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Throw Me a Lifeline: A Comparison of Port Cities with Antithetical Adaptation Strategies to Sea-Level Rise

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THROW ME A LIFELINE: A COMPARISON OF PORT CITIES
WITH ANTITHETICAL ADAPTATION STRATEGIES TO SEA-LEVEL RISE

by

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DOCTOR OF PHILOSOPHY

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OLD DOMINION UNIVERSITY
May 2018

Approved by:

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David Earnest (Member)

Hans-Peter Plag (Member)

Steve Yetiv (Member)
ABSTRACT

THROW ME A LIFELINE: A COMPARISON OF PORT CITIES WITH ANTITHETICAL ADAPTATION STRATEGIES TO SEA-LEVEL RISE

Claudia Marie Risner
Old Dominion University, 2018
Director: Dr. Regina Karp

Sea-level rise (SLR) is a manifestation of climate change that is particularly hazardous to port cities that must remain on the waterfront to function, yet are increasingly battered and flooded by encroaching storms, and sinking into the rising saltwater. Despite sharing a common high level of risk, port cities are choosing antithetical adaptation strategies that range from hard-engineered structural flood protection, to behavioral modifications, to innovative soft-engineered measures, to doing nothing at all. Why is this? Are transnational city networks, such as C40 Cities, a lifeline to drowning cities? Do differences in governance structure, financial capacity, risk tolerance to the hazard, or the influence of special interest groups matter?

These factors and the interplay of civil, public, and corporate actors in the context of changing environmental conditions are examined in this cross-disciplinary qualitative study to understand their effects on adaptation decision-making processes over time. Four at-risk global port cities—Venice, Rotterdam, Guangzhou, and Miami—were selected for comparison based on their antithetical adaptation strategies of retreating, climate proofing, innovating, and denying.

The Panarchy model of nested four-stage adaptive renewal cycles frames the ongoing and cross-scalar interaction of stakeholders and special interest groups at the city, national, transnational, and international levels. This methodology enables the identification of patterns, power distributions, and path dependencies that contribute to appropriate or maladaptive adaptation.

As is characteristic of complex adaptive systems, this study finds that decisions cannot be correlated with a single factor. For those cities that display key characteristics of resilience, SLR is a catalyst for proactive and appropriate adaptation. For others, socio-economic and
socio-political factors trump environmental factors in deciding whether, when, and how a city decreased its risk to SLR hazard.
I dedicate this dissertation to both the idea that society only truly thrives when we have a harmonious relationship with the environment that is our life-support system, and to the collective whose efforts make that idea our reality.
ACKNOWLEDGEMENTS

First, I want to thank my husband and editor-in-chief, Rick Moody, whose support, critical review, patience, and love made this the wonderful experience that it has been. I also want to thank my mentors, Dr. David Earnest who guided, encouraged, and invested so much time in me over the years, despite the miles and time zones, on this journey of exploration and learning; Dr. Regina Karp who advised me through three years of coursework and supported and guided me toward closure; Dr. Steve Yetiv who planted the seed of this idea of networked cities as political agents in a global order of nations and provided parsimonious insight to keep me on track; and Dr. Han-Peter Plag who inspired me to bring the Earth back into our international political economy and encouraged me at every opportunity. In the course of this process I feel that I have gained immensely from my association with these scholars, with the most important benefit being their friendship.

A note of thanks to Ms. Grazia Coletti and boat captain Manuel Eulisse who provided both logistical assistance and valuable local knowledge insight to the Venice case study during my field research trip in November 2016. Nothing compares to walking in their galoshes and seeing the effects of SLR first hand.

I also want to thank my classmates, colleagues, and friends whose humor, understanding, and insight provided the feeling of solidarity one needs to accomplish such a personal milestone. A special call out to Mary Bell, Dawn Driesbach, Joanne Fish, and Christina Slentz for their encouragement and friendship. I hope to repay those still on their journeys and pay it forward to anyone considering such an endeavor. And to my family members, Valerie, Randy, Joe, and Andrew who read my drafts and provided helpful feedback and encouragement along the way. Lastly, thanks to my mom and dad who instilled in me a love of learning and a sense that nothing would ever be beyond my reach.
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<td>100 Resilient Cities</td>
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<td>AAL</td>
<td>Average Annual Losses</td>
</tr>
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<td>ACCCRN</td>
<td>Asian Cities Climate Change Resilience Network</td>
</tr>
<tr>
<td>AG</td>
<td>Adaptive Governance</td>
</tr>
<tr>
<td>AMOC</td>
<td>Atlantic Meridional Overturning Circulation</td>
</tr>
<tr>
<td>AR4</td>
<td>Fourth Assessment Report</td>
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<tr>
<td>AR5</td>
<td>Fifth Assessment Report</td>
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<td>BW-12</td>
<td>Biggert-Waters Flood Insurance Reform Act of 2011</td>
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<td>C40 Cities</td>
<td>C40 Cities Climate Leadership Group</td>
</tr>
<tr>
<td>CCS</td>
<td>Carbon Capture and Storage</td>
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<td>CDBC</td>
<td>China Development Bank Capital</td>
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<tr>
<td>CDC</td>
<td>Connecting Delta Cities</td>
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<tr>
<td>CO₂</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>COP 21</td>
<td>Conference of the Parties</td>
</tr>
<tr>
<td>CPC</td>
<td>Communist Party of China</td>
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<tr>
<td>CRF</td>
<td>City Resilience Framework</td>
</tr>
<tr>
<td>CRO</td>
<td>Chief Resilience Officer</td>
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<tr>
<td>ES</td>
<td>Ecosystem Services</td>
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<td>EU</td>
<td>European Union</td>
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<tr>
<td>FCPA</td>
<td>Florida Community Planning Act</td>
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<td>FEMA</td>
<td>Federal Emergency Management Agency</td>
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<td>GHG</td>
<td>Greenhouse Gas</td>
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<td>GOP</td>
<td>Grand Old Party</td>
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<tr>
<td>IEA</td>
<td>International Energy Agency</td>
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<tr>
<td>INGO</td>
<td>International Non-governmental Organization</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<td>IPE</td>
<td>International Political Economy</td>
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<td>IR</td>
<td>International Relations</td>
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<tr>
<td>OECD</td>
<td>Organization for Economic Cooperation and Development</td>
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<tr>
<td>NFIP</td>
<td>National Flood Insurance Program</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-governmental Organization</td>
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<tr>
<td>NOAA</td>
<td>National Oceanographic and Atmospheric Agency</td>
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<tr>
<td>NSA</td>
<td>Non-state Actor</td>
</tr>
<tr>
<td>NYC</td>
<td>New York City</td>
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<tr>
<td>PPP</td>
<td>Public-Private Partnership</td>
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<tr>
<td>PRC</td>
<td>Peoples Republic of China</td>
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<tr>
<td>RAT</td>
<td>Resilience, Adaptability and Transformability</td>
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<tr>
<td>RCP</td>
<td>Representative Concentration Pathways</td>
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<tr>
<td>RPA</td>
<td>Rotterdam Port Authority</td>
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<tr>
<td>Acronym</td>
<td>Full Form</td>
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<tr>
<td>SES</td>
<td>Socio-ecological System</td>
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<td>SFRCCC</td>
<td>Southeast Florida Regional Climate Change Compact</td>
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<td>SLR</td>
<td>Sea level rise</td>
</tr>
<tr>
<td>TAN</td>
<td>Transnational Advocacy Network</td>
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<tr>
<td>TCCG</td>
<td>Transnational Climate Change Governance</td>
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<tr>
<td>TCN</td>
<td>Transnational City Network</td>
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<tr>
<td>UN</td>
<td>United Nations</td>
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<tr>
<td>UNESCO</td>
<td>United Nations Educational Scientific and Cultural Organization</td>
</tr>
<tr>
<td>UNISDR</td>
<td>United Nations International Strategy for Disaster Risk Reduction</td>
</tr>
<tr>
<td>U.S.</td>
<td>United States of America</td>
</tr>
<tr>
<td>USACE</td>
<td>United States Army Corps of Engineers</td>
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<tr>
<td>WHS</td>
<td>World Heritage Site</td>
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## GLOSSARY

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<td>Adaptation</td>
<td>The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. (IPCC, 2013)</td>
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<tr>
<td>Hazard</td>
<td>A process, phenomenon or human activity that may cause the loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. (UNISDR)</td>
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<td>Network</td>
<td>Forms of organizations characterized by voluntary, reciprocal, and horizontal patterns of communication and exchange. A network’s primary functions are information sharing, capacity building and implementation, and rule setting. (Keck and Sikkink, 1998)</td>
</tr>
<tr>
<td>Panarchy</td>
<td>A conceptual framework to account for the dual, and seemingly contradictory, characteristics of all complex systems—stability and change. It is an integrative framework, bringing together economic, ecological, and social models of change and stability to account for the complex interactions among these different areas and different scale levels. It connects ecosystem functioning with economic activities and human institutions for managing the relation between the two. (The Sustainable Scale Project at Resilience Alliance)</td>
</tr>
<tr>
<td>Resilience</td>
<td>The capacity of a system to absorb disturbance and re-organize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks. (Folke, 2006, refs Walker et al., 2004)</td>
</tr>
<tr>
<td>Social Capital</td>
<td>The networks and resources available to people because of their connections. (Aldrich, 2012)</td>
</tr>
<tr>
<td>Transformability</td>
<td>The capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable. (Walker et al., 2004)</td>
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<tr>
<td>Transnational Governance</td>
<td>Networks operating in the transnational sphere authoritatively steering constituents toward public goals. (Bulkeley et al., 2014)</td>
</tr>
<tr>
<td>Urban Resilience</td>
<td>The capacity of cities (i.e., individuals, communities, institutions, businesses, and systems) to survive, adapt, and thrive in the face of...</td>
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stress and shocks and even transform when conditions require it.
(Rockefeller Foundation's ACCCRN, 2015)
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CHAPTER 1

INTRODUCTION

Puzzle and Research Questions

Venice and Rotterdam are sinking. Rotterdam’s policy is to climate proof; Venice’s policy has been to retreat upstairs. Fish swim in the city streets of Miami during King tides and the Florida Governor outlaws the term “sea-level rise”, while the Chinese government spends $200 million turning the chronically-flooded Pearl River Delta city of Guangzhou into a sponge city.¹ Miami is denying and Guangzhou is innovating. Their adaptation policies are in stark contrast despite facing the same environmental threat—rising sea levels. Why have these four port cities chosen antithetical policies to an increasingly existential threat? This is the puzzle.

The Intergovernmental Panel on Climate Change (IPCC) puts the rate of change of this manifestation of global warming into an historical perspective. “The rate of sea level rise (SLR) since the mid-19th century has been larger than the mean rate during the previous two millennia.”² This pales in comparison to the 410 foot (125 meter) SLR that occurred during the 20,000 years since the last ice age, however, the recent period of accelerated SLR in the context of dense urban coastal settlement and global ports completely changes the threat.³ Although history is not always an indicator of future events, scientists suggest that this recent environmental phenomenon and the social behavior that contributes to it have formed a positive feedback loop with negative consequences. How bad can it get? If all of the ice melted at the poles and mountaintops,

making ours an iceless world, the sea would rise 216 feet (65.8 meters).\footnote{“What the World Would Look Like if All the Ice Melted,” \textit{National Geographic Magazine}, September 2013, \url{https://www.nationalgeographic.com/magazine/2013/09/rising-seas-ice-melt-new-shoreline-maps/} (accessed 15 Nov 2017).} Even though that would take 5,000 years to happen, the ice melts and fills the seas a day at a time making this a chronic issue that only worsens for those living at sea level.

http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf

Each of these four cities is a global port whose location at the water’s edge forms its identity, and is the reason for its settlement and rise to prominence. For these sinking, flooding, and storm-battered cities to thrive in the future as portals to the world economy they must develop a closer and more sustainable relationship with their dynamic environments. And, they must do so in a manner that acknowledges the probable risks and potential opportunities inherent in changing conditions. They must adjust, adapt, and transform. Some do.

The question, then, is \textit{Why do some cities adapt to SLR while others do not?} This question includes \textit{Why is there variance in the method and timing of adapting to a similar threat?} \textit{Which factors and conditions influence the decision-making process?} \textit{What are a city’s adaptation policy options?} \textit{How do they adapt?} \textit{Who can cities turn to for a lifeline to stay afloat?} \textit{How do transnational city networks (TCNs) help?}

City residents and visitors alike observe the empirical evidence of SLR-related flood and storm damage. Thus, there is not a lack of hazard and risk awareness, although there is uncertainty as to where, when, and to what extent the effects will be felt. The media coverage of individual disasters and the scientific data of aggregate trends and forecasts are openly discussed by the general public. This information is then filtered through various political, economic, and social lenses for a thorough rehashing in heated debates. These debates expose the different perceptions, normative beliefs, and interests of stakeholders that influence the decision-making process in politically contextualized situations. There are internal stakeholders and external special interest groups with strong economic interests in maintaining the status quo that buy political support and derail data-based conversations to delay decisions for change. There are also change agents pushing in different directions, including those with solutions that are costly, unproven, and
disruptive. Maladaptive policies will not increase the resilience of cities and will prove costly to implement. They are implemented because those who stand to profit have a stronger voice than the others.

How city authorities facilitate an inclusive discussion that progresses to effective climate action is the crux of the adaptation process. This process manifests as one of four broad policies for reducing vulnerability: mitigation, adaptation, mitigation and adaptation, or inaction. Mitigation measures lessen the causes, are viewed as proactive, and consist of decreasing carbon dioxide and other greenhouse gas (GHG) emissions to limit the magnitude and/or rate of long-term global warming induced climate change.\(^5\) Adaptation is defined by the IPCC as “the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.”\(^6\) This definition highlights the nature of adaptation as being either a response to, or preparation for, major weather events. Whether a city’s adaptation method is an engineered measure that keeps the water at bay (i.e., storm surge prevention) or allows it to pass through to aquifers (i.e., flood avoidance), or is a behavioral measure such as urban land use planning that shifts populations inland or builds up a buffering natural coastal ecosystem to reduce exposure; port cities have policy options that can reduce their risk.

A comprehensive strategy is a policy mix that includes mitigation of the causes of global warming over the long term and adaptation to lessen the effects of global warming in the short to medium term. Adaptation and mitigation policies are considered as either substitutes or as complementary, depending on one’s perspective being either economics or climate science based.\(^7\) Increasingly, in the literature and in practice, the most effective policy requires both mitigation and adaptation. In practice, the fourth option of inaction

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means that a city foregoes implementing proactive disaster risk reduction measures to reduce its vulnerability. Consequently, once a disaster strikes the city has a more extensive and expensive disaster recovery and rebuilding effort with which they must contend. As recovery costs mount, a catastrophic weather event exposes the folly of ignoring the issue and spurs decision makers to take action.

Inherent in understanding adaptation is being knowledgeable of related concepts. The goal of adaptation is to increase the resilience of the system, whether it is a person, an ecosystem, or a city. Resilience is most simply defined as the ability of a system to recover from stress. Additional characteristics of resilience include the system’s ability to deflect, absorb, bounce back from, and learn from disturbances without changing its fundamental nature and identity. For complex systems, Root defines resilience as “the capacity to survive shocks: the ability to reorganize during intense cycles of change and remain in a cohesive state”. These definitions include reference to the state of the system and a desire to remain essentially the same, not stable or at equilibrium, but within a basin of functionality. In the context of a city this means the city continues to function in the manner to which the global economy relies upon it. For example, if a port city adapts to SLR in a manner that preserves its shipping capability then the adaptation measures served to increase its resilience to storms. If, on the other hand, a catastrophic storm exceeds the port’s resilience capacity and it is unable to function as a global transportation hub, then the city must rebuild in a transformational manner to survive future storms.

Transformability is the last of the concepts useful to define. As implied above, this is “the capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable.” A lack of this capacity leads to the death of the organism or the collapse of a city or state, such as the numerous examples of poor societal decisions that proved fatal in Jared Diamond’s book on the topic entitled Collapse. These concepts will be further discussed and operationalized in chapters two and three.

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10 Jared Diamond, Collapse: How Societies Choose to Fail or to Succeed (New York: Penguin Group, 2005).
This study seeks to understand the interactions of key actors in the private and public sectors and civil society in the context of their economic and political conditions in a port city with a high threat of SLR-related hazard. The unit of analysis is the city, however the study is attuned to the nested and interdependent nature of cities composed of neighborhood communities and inextricably networked horizontally with other global cities and vertically with national and international agents. This multitude of stakeholders has a voice, power, and influence on the city’s ongoing decision-making process of climate adaptation action. At the same time there is a segment of each city’s population with minimal agency whose voice is seldom heard, which represent the most vulnerable and who disproportionately bear the costs of inaction or maladaptive policies. In a nutshell, what is the political-economy of a city’s adaptation to SLR?

**Why this is important?**

A call for action on the topic of adaptation to climate change has been issued in response to the deafening silence in the political science literature to date. The majority of climate change research and action has focused on mitigation. Adaptation has been relegated to nations and cities in the developing world—the Global South policy-takers who bear the diffused, but locally concentrated, costs associated with global warming while the Global North policy-makers reap the concentrated benefits of industrialization.

Javeline argues that “adaptation is fundamentally political” and that the lack of research by political scientists is actually an obstacle to adaptation.11 This is because the extensive interdisciplinary work being done on this new critical field includes myriad scholars with the glaring exception of political scientists, which leaves those questions that they are uniquely trained to answer unanswered. Adaptation issues “are less about science and more about political, social, and economic behavior and the institutions that facilitate or obstruct that behavior.”12 She goes on to list 15 political science subfields and research questions. Those relevant to this study include comparative politics, political economy, social capital, subnational governments, and urban politics.

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12 Ibid., 421.
Part of the criticality of this issue is the extreme costs associated with it. In his comprehensive and renowned 2006 economic review of climate change, Stern explained the mounting and substantial economic costs of climate policy inaction. “Climate change presents a unique challenge for economics: it is the greatest and widest-ranging market failure ever seen.”13 Stern identifies SLR as a threat to major world cities, but explains that the cost will ripple throughout the economy.14

Keohane magnified Javeline’s message calling for action on climate action saying “it is distressing to observe the slow response from political science as a discipline.”15 He identified one of the key contributions that political scientists can make as being a reframing of the climate problem. By focusing on the incentives that political actors face due to the economic opportunities inherent in climate adaptation action, rather than the costs borne by current voters, public policy decisions would be better shaped.16

Together these political science and economics scholars cite a glaring need for research to which this study intends to contribute—at the city level. This is why. Cities are the economic engines of the global economy and home to more than half of the world’s population, and, as such, they produce 75% of the world’s GHG emissions. At the same time, coastal cities are recipients of the consequences of climate change as manifest in SLR-related disasters. They are bearing the extraordinary costs of flooding and extreme storms. Thus, although the effectiveness of adaptation is difficult to measure because of its preventive nature, in contrast to the ease of measuring GHG emissions and temperature, cities are incentivized toward adaptation climate action for survival. Exposing the internal and external actors, processes, and institutions that counteract a city’s logical quest for increased resilience to an acknowledged hazard is a step toward addressing the issues that block adaptation.

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14 Ibid., 5, figure 2.
16 Ibid., 20.
This paper is laid out as follows. Chapter two reviews the relevant literature on theories in the fields of Socio-ecological Systems, Resilience and Panarchy, Transnationalism and Climate Change Governance, and Urban Policy Learning with a discussion on these theories’ applicability to city level relationships on the issue area of climate change. Chapter three is the research design beginning with the longitudinal and multi-scalar Panarchy framework as an analytical tool to aid understanding the adaptation process and resilience of a city’s relationship with its environment. After the framework discussion, I explain the choice of the comparative case study methodology and identify the primary interdependent political and economic factors (i.e., independent variables) examined to gain insight to their effect—both directional and intensity—on a city’s resilience (i.e., the dependent variable). Next is an overview of climate action with a strong focus on adaptation strategies including the development of a typology of adaptation approaches and options. The chapter closes with the case selection of four port cities with antithetical adaptation strategies to a common SLR hazard. Chapters four through seven are individual case studies of Venice, Rotterdam, Guangzhou, and Miami, respectively. Chapter eight is the comparative analysis and conclusions. This last chapter closes with implications for the contribution these qualitative case studies make to the literature and suggestions for further research.
CHAPTER 2

LITERATURE REVIEW

The effects of a warming climate are felt to different degrees around the world. For coastal communities it is becoming more difficult to keep the water at bay. SLR, land subsidence, “nuisance flooding,” and more intense and more frequent storms are exacting an increasing toll.\(^1\) Storms batter waterfront property and erode beaches, floods ruin built infrastructure and disrupt lives, flood insurance rates are going through the roof, and community residents now worry about their evacuation plan. People living on the edge of the sea are becoming increasingly on edge as their relationship with the coastal environment turns tumultuous. It wasn’t always like this. What happened?

Industrialization, urbanization, over-population, energy consumption, fossil fuel and water extraction, wealth aggregation, pollution, global warming, climate change, ice sheet and glacier melting, ocean acidification, and SLR happened. These are twelve characteristics of life in the 21\textsuperscript{st} century. The first six phenomena represent human activity that started a few centuries ago on a small scale. As the rate and scale of these social behaviors increased exponentially, the phenomena became megatrends that, in aggregate, challenged the coping ability of the environment within which society exists—our Earth life support system. Human activity created new conditions for the environment and forced reactions that manifest as the last six environmental phenomena. Our global ecosystem’s homeostasis has been upset. The period of relative climate stability, within which rapid and extensive societal development occurred, may be ending. We are in the Anthropocene period, the timeframe within which human activity is the dominant influence on geological conditions and processes.\(^2\)

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Climate stability is considered to have been a necessary condition for our development to date. However, it is not yet known if the condition of climate instability is sufficient to destabilize civilization. Nor is it clear if human behavior can mitigate the anticipated damage of future weather-related hazards through corrective management of natural resources. Whether mitigation measures can slow or stop the trend of increasing global temperatures, though, is not relevant to the decision to adopt adaptive measures to reduce exposure, reduce vulnerability, and build resilience.

Now we return to my research questions: *Why do some cities adapt to SLR while others do not? How do they adapt and which factors/conditions influence adaptation decision making?* To decide to adapt to an environmental condition requires a thorough understanding of the situation, an accurate assessment of what effects the conditions will have on the adapter, and a list of options that includes an associated level of risk reduction, the cost of adopting *and* the cost of not adopting an adaptation strategy. The literature on socio-ecological systems (SESs) is a good place to begin to gain insight into how others have pursued understanding the dynamics of the human-environmental relationship.

**Socio-ecological Systems**

The holistic perspective of the linked systems of humans and the environment is of two inseparable components of a complex and dynamic SES. Berkes and Folke (1998) coined the term SES to give equal weight to the social and ecological dimensions of their analysis of the linked system of people and nature in the context of natural resource management.³

As awareness of the impact of social actors and institutions on the environment increases, and as Mother Nature displays the potential force of environmental reactions that threaten access to the natural resources upon which our survival depends, people have become increasingly interested in understanding this interdependent relationship. This

understanding necessitates scaling down to the local level for observation, data collection, pattern detection, and inductive reasoning for theory building.

The SES concept provides “a powerful analytical frame for understanding the interlinked dynamics of environmental and societal change” (Fischer et al., 2015: 145). The dynamics are social relationships or ecological feedbacks, depending on one’s perspective as emanating from their social or earth science’s position, respectively. The SES frame provides a nexus for political economists, environmental institutionalists, ecological economists, operations researchers, landscape ecologists, climate experts, and others. Through this connection they may collaborate using an interdisciplinary systems approach to address the complex issues of natural resource management. The concept is widely acknowledged as critical to understanding the interlinked dynamics of change (Fischer et al., 2015).

Political economists approach these issues from the viewpoint of governance and behavior. Ostrom’s earlier work (1990, 1998) on developing a behavioral theory of collective action served to refute Hardin’s (1968) dire predictions that individuals were rational maximizers of short-term, relative gain not prone to cooperate under their own impetus. Common pool resource research (Ostrom 1998 and 1999; Berkes, Colding, and Folke 1998 and 2003) proved that there were conditions under which individuals cooperated for the group’s long-term interest by self-organizing, monitoring, and making and enforcing rules. These are the building blocks of governance—self-governance.

Ostrom (1999, 2007, and 2009) was an early adopter of the SES concept, which she developed and refined into a multilevel, nested framework that facilitated the methodical analysis of relationships and outcomes in the context of specific resource systems, resource units, governance systems, and user conditions. Application of Ostrom’s analytical tool has been used extensively for research on forests, fisheries, meadowlands, irrigation systems, and other common pool resource environments for comparison to detect patterns of behavior and isolate factors and their values that would be most likely to motivate users to self-organize (Ostrom 2009). Ten of the key factors that emerged are: size of the resource system, productivity of systems, predictability of systems, resource unit mobility, number of users, leadership, norms/social capital, knowledge of SES, importance of resource to users, and collective choice rules. All of these variables matter and correlate with self-
organization rather predictability, but are strongly contextual, negating the ability to make generalizations. Within this context, however, the research findings suggest that the problem of overcoming social dilemmas through self-organizing, or collective action, is achieved by building conditions of reciprocity, reputation, and trust (Ostrom 1998).

In addition to this list of conditions are communications, institutionalization, and autonomy, which were found to be necessary characteristics (Poteete, Janssen, and Ostrom 2011). Necessary, because in their absence resource users acted independently and failed to develop a sustainable relationship with the ecosystem within the SES.

As behavioral patterns formalized into institutions and governance, Ostrom (1999 and 2012) found that polycentric governance, characterized by nesting, networking, and decentralized authority, achieved net benefits at multiple scales. These results prompted policy recommendations for polycentric governance of resources in the commons (Poteete, Janssen, and Ostrom 2011; Ostrom 2008 and 2010), in direct contrast to Hardin’s policy recommendation for central governance that, in practice, often provoked the rational maximizer’s tendencies toward uncooperative short-term relative gain and produced tragic outcomes. However, it is unclear how generalizable this theory is and to what extent the results are reproducible in a scaled and urban setting.

The SES concept is a systems approach to analyzing complex adaptive systems that holds promise for application in this study. However, the framework’s primary focus is on the management of natural resources and the preservation of ecological services in a small-scale common pool resource situation. This is not the focus of my study, which is concerned with why and how some cities adopt climate adaptation policies and others do not. The focal direction is opposite and the scale is much larger. In these respects the SES framework inverts my research question: it focuses on how governing institutions may affect changes in the ecology, whereas this study is concerned with how the dynamics of climate change may induce, or fail to induce, changes in governing institutions.

**Resilience and Panarchy**

Ecologists’ research focuses on the resilience of SESs and uses case studies to identify factors that increase a system’s resiliency. Berkes, Colding, and Folke’s (2003)
findings were that three conditions increased resilience: redundancy and diversity for both
the political and ecological components, risk-spreading strategies to absorb the shock of
abrupt changes in ecosystems, and the inclusion of local knowledge and scientific
techniques which makes management of the resources and system more adaptive. They
argued that building resilience into both components of the SES has a two-fold positive
effect. It enables better management of natural resources and it increases human capacity
to adjust to change. These findings built on their earlier work (Berkes and Folke 1998) of
case studies that centered on the relationship of governance at different levels and the
sustainability of local management over time. The authors found that adaptive
management systems are the most effective and they developed guiding principles that
would increase the resilience of systems to minimize the loss of future options. Adaptive
management “flows with nature,” uses local ecological knowledge, promotes local self-
organizing and learning, and values resilience and sustainability (Berkes and Folke 1998).

These studies articulate the idea that the social system must be attentive to
fluctuations and disturbances, often human induced, that may destabilize the ecosystem
and then they must proactively adapt management of the resources to return it to its basin
of equilibrium. If the system collapses or shifts to a new regime, the results are quite
unpredictable and the specific ecological resources or services it had provided may no
longer be available.

In practice the attentiveness of resource users and system managers varies, which
leads to fluctuations in the health of ecosystems that provide services. Not all
interdependencies are created equal. Daw et al., (2016) developed a concept of elasticity in
ecosystem services (ES), which describes the sensitivity of human wellbeing to variation
and change in an ecosystem upon which they have an economic interest. This is similar to
the concept of price elasticity of demand in economics, which measures the responsiveness
of demand to a change in pricing. Relationships are characterized by high, low, or negative
elasticity. High and low elasticity reflects the tightness or decoupled nature of relationship,

Coulthard, C. Sandbrook, S. Perry, S. Bandeira, N.A. Muthiga, B. Schulte-Herbrüggen, J. Bosire, and T. R.
McClanahan, “Elasticity in Ecosystem Services: Exploring the Variable Relationship between Ecosystems and
respectively. Negative elasticity reflects an inverse relationship. An example of negative elasticity, sadly, is the “environmentalist’s paradox” in which people’s wellbeing improves in the short term as the quality of the ecosystem declines (Daw et al. 2016: 2). The more elephants that poachers kill for their tusks, the more money they make, but to the demise of the elephant herds and future poaching.

The elasticity concept emphasizes the variance of the dependence of people on the natural capital of their ecosystem. The researchers developed a chain-of-events framework that maps the social and ecological links between ecosystems and the wellbeing for different beneficiaries (Daw et al. 2016: 9). The level of detail allows distinguishing between the poor and wealthy ES users, takes into consideration the availability of substitutes and the temporal aspect of short and long-term benefit, and it scales from the individual level to family to the aggregate.

As was the case with the SES framework, despite the ES Elasticity framework being better suited for case studies of smaller common pool resource situations, the concepts are useful. Both frameworks contribute insight to patterns of behavior, expose conditions that correlate between the social and ecological components of the SES, and generate policy recommendations for resource and ecosystem management. However, the frameworks are complicated and require considerable data, and neither has been applied at a scale as large as a city. East African coastal ecosystems; shell clam fisheries in Maine; the rain forest in Ara, Nigeria; pastoralists in the fragile semi-arid climates of the Sahel; and water basins in California, U.S. are the appropriate size for these detailed frameworks.

In addition to scale, there is another issue that needs to be addressed when attempting to apply these frameworks to cities that is not present in the smaller common pool resource scenarios. The considerable amount of built physical infrastructure, which is necessary to accommodate the density of urban population and activity, significantly impacts the natural environment. The urban ecology literature (McPhearson et al. 2016: 10-11) explains that “urban infrastructure mediates the relationships between human activities and ecosystem processes and may exacerbate or mitigate human impact, depending on how it is developed.” These authors propose a social-ecological-technical/built system to elevate the importance of physical infrastructure, which they suggest acts as an intervening factor.
By framing climate change as a global collective action problem in which many participants must take action to avoid the common bad of a polluted environment, we can extrapolate the lessons and recommendations of SES research and apply them to the problem of global warming. Ostrom (2010) did this in addressing mitigation. She makes the case for polycentric approaches to reducing GHG emissions and heralds the emerging polycentric governance system as important climate change action.

Another description of climate change governance is as a “regime complex: a loosely coupled set of specific regimes” (Keohane and Victor 2011: 7). These authors argue that such a complex, characterized by its adaptability over time and flexibility across issues, has advantages over any other political regime. For their advantages to outweigh their liabilities, however, a regime complex must be at the higher end of the scale for six criteria: coherence, accountability, determinacy, sustainability, epistemic quality, and fairness. Otherwise they risk being “associated with chaos, a proliferation of veto points, and gridlock” that would deter both public and private stakeholders from cooperation (Keohane and Victor 2011: 16).

Young et al. (2006) apply the paradigm to scale by linking globalization with SESs. The study examines the interactions between global social change and global environmental change and identifies the key features of an SES as resilience, vulnerability, and adaptability. The authors note that globalization in the social system is characterized by mega-trends, such as urbanization and natural resource extraction, that supersize the impact on the environmental system. At the same time, the information technology revolution compresses time and space in the social system, which accelerates the rate of change exponentially.

The net result negatively impacts the ecological component that has not been able to adapt to the same extent and at the same speed. The two interdependent components are out of sync and the resultant asymmetry of the relationship within the SES is not sustainable. The outcome will depend, in part, on whether the feedback mechanisms amplify or dampen the changes (Young et al. 2006: 307). If the change is beyond the resilience capacity of the ecological component it may move out of its stability domain to another, which would be a transformational adaptation, or it may collapse. From a management perspective the biggest problem lies in knowing what will be the full effect of
the asymmetry or knowing when a system is nearing a threshold. The problem of threshold detection is a problem that scales with the size of the SES and becomes critical for a city, and it has not been discussed in the literature. Is it even possible to know if a city is nearing a threshold? Ten years past New Orleans’ catastrophic weather event it remains unclear if the city will fully rebuild and identifying thresholds pre-extreme weather event seems impossible.

On a smaller scale, efforts to quantify resilience resulted in identifying a behavior of ecosystems with declining resilience that correlated with its proximity to a threshold. The phenomenon of “critical slowing down,” referring to the system’s slower recovery from small disturbances as it neared a tipping point, was observed and determined to be a characteristic of low resilience (Scheffer et al. 2015). The critical nature of this slowing is that when it occurs—and it does not occur consistently in all natural systems—the system transitions or collapses (Dakos et al. 2013). Theoretically, close monitoring of an ecosystem that displays slowing recovery behavior would be a useful resource management tool in that it would spur intervention to boost the system’s resilience. Managers could heed the early warning indicator to prevent transition to another regime. However, this is not the case in practice because of the wide range of situations in which systems do not display this behavior before transition or they exhibit false positives (Dakos et al. 2013: 6-7).

The unpredictability of post-transition states, thresholds, and the dynamic nature of systems are of concern to another academic group, landscape ecologists, who prioritize sustainability in relationships between people and the environment. They bring the concept of Spatial Resilience, with its focus on the importance of spatial attributes such as location, connectivity, and context, to the resilience and SES literature (Allen et al. 2016, Cumming 2011).5 Cumming explains that spatial resilience is “based on the idea that spatial variation in patterns and processes at different scales both impacts and is impacted by local system resilience” (2011: 899). This can be compared to the concept of social capital, which is also multi-scalar, and its positive contribution to societal resilience. Fragmented neighborhoods or groups within a community that are socially excluded have

5 Craig R. Allen, David G. Angeler, Graeme S. Cumming, Carl Folke, Dirac Twidwell and Daniel R. Uden, “Quantifying Spatial Resilience,” Journal of Applied Ecology 53 (2016): 627. Spatial resilience is defined as “the contribution of spatial attributes to the feedbacks that generate resilience in ecosystems and other complex systems, and vice verse.”
a lower level of resilience to disturbances and take longer to recover from disaster, or they do not recover (Aldrich 2012, Klinenberg 2002). This lack of connectivity also negatively affects the level of resilience of forests, wetlands, and other ecosystems (Cumming 2011: 899). The ecological memory from external systems that can aid in the focal system’s reorganization process are not available to spatially separated systems (Allen et al. 2016).

The Allen et al. study warns that relatively small stressors can cause relatively abrupt and non-linear changes in ecosystems when their resilience is exceeded. This is an example of the emergence of new behavior characteristic of complex systems. Climate change is a phenomenon that landscape ecologists consider to be a rich source of stressors that will push ecosystems beyond their resilience capacity. To avoid the potential loss of beneficial ecosystem resources and services, managers can focus on making systems more resilient and guiding transformation in a direction toward a new stability basin that maximizes possible future benefits.

In the resilience literature, a system that transforms is perceived as going to that place marked on old sailing charts with the warning “Here be dragons,” those dangerous and unexplored territories best left in the horizon. Understanding what causes systems to go beyond thresholds and begin the process of transformational change, then, is critical, and Gunderson and Holling’s (2002) seminal work explores the subject thoroughly. They develop the Panarchy concept, which represents universal nature (i.e., the Greek god Pan) and is associated with unpredictable change, based on the premise that “in dynamic systems, only uncertainty is certain, and it arises from multiple causes” (Wuethrich 2002: 42). In fact, stability of one system is found to be a cause for destabilization in the other system (Gunderson and Holling 2002: 411). The process of change in the interdependent components of the SES is the process of adaptation within the single system. An ongoing, scaling, and cascading adaptation process is characterized by emergence of new behavior.

They developed a framework of adaptive change based on three properties found to shape future social and ecological responses: the range of potential change options, the degree of connectedness between processes and factors, and the system’s resilience (Gunderson and Holling 2002: 33). The concept and framework of Panarchy facilitated further expansion in the resilience research field. “Resilience, Adaptability and Transformability” (RAT) (Walker et al. 2004), “Thresholds in Ecological and SESs” (Walker
and Meyers 2004), and Resilience Thinking (Walker and Salt 2006) all contribute significantly to better understanding resilience.

Walker et al. (2004) identifies RAT as three complementary attributes of an SES that govern its stability dynamics and determine its future trajectory. These three broad concepts are related. Resilience is defined as the capacity of a system to “stay in the same basin of attraction,” thus not crossing a threshold and finding another equilibrium (Walker et al. 2004: 6). Resilience comprises four critical aspects: latitude within the stability basin, resistance to change, precariousness or proximity to the threshold, and panarchy or cross-scale interactions. The first three aspects are spatial characteristics that describe a system’s current location relative to the equilibrium state to which it is attracted. Panarchy addresses the cross-scale effects of coarser and finer scale systems that influence the trajectory of the focal system, a point made by the landscape ecologists in the discussion of spatial resilience. It includes consideration of where the focal system is in its four-phase adaptive cycle.

In contrast to the conceptual definition mentioned in chapter one, Walker et al. define adaptability as the manager’s capacity to influence the system’s resilience by affecting change in the four components. This acknowledges the dominance of human actions in SESs and reflects the collective capacity of social actors to intentionally manage a system’s resilience to avoid leaving a stability landscape. Social managers are endogenous actors in a dynamic SES that changes in reaction to endogenous processes and exogenous drivers, such as the effects of climate change.

Transformability, as defined earlier, refers to the capacity to create a fundamentally new system when the existing system is no longer viable (Walker et al. 2004). While system destabilization, tipping points, and crossing thresholds often have a negative connotation due to the unpredictability associated with the high degree of change, transformation can be positive. Transformation underscores the role of managers in influencing a system toward a new stability landscape, and the significance of regime change and thresholds. To better understand these dynamics the Santa Fe Institute and Resilience Alliance jointly developed a database of linked SESs that either transform to an
alternate state or remain in a stable state. Thresholds, controlling variables, the nature and direction of feedbacks, and regime shift can be more thoroughly examined and categorized so patterns may be discerned in the aggregate through use of this database (Walker and Meyers 2004). The database includes SESs that grapple with both endogenous societal disturbances, such as the over extraction of natural resources that led to the collapse of society on Easter Island, as well as those that face exogenous environmental disturbances, such as climate change that has caused over salinization of Hudson Bay, Canada. Primarily the database is populated with SESs at a smaller scale than a city.

Resilience Thinking serves as a primer on resilience that brings together all of the concepts, factors, and interrelationships and then applies the Panarchy concept to explain the adaptive cycle across scale and over time (Walker and Salt 2006). The adaptive cycle forms a framework for Panarchy that is used to guide my study and is discussed further in chapter three.

Walker presents resilience with a strong ecological focus. In the social ecology literature it is presented a little differently, which increases awareness of the sociocultural (Stokols, Lejano, and Hipp 2013) dimensions of resilience. It is conceptualized as transactional processes between people and the environment, and as multi-capital formation. The transactional approach emphasizes the bidirectional nature of the exchange (i.e., response and counter-response) of capitalized assets. Assets are either material resources, such as natural capital, economic/financial capital, human-made environmental capital or technological capital, or human resources, which are social, human or moral capital (Stokols, Lejano, and Hipp 2013: 7).

This categorization of assets and analysis of transactional exchanges between people and the environment can identify those high-leverage points of intervention that benefit resource managers. The processes are reciprocal cycles of mutual influence that either produce a good fit between society and the surroundings or do not. The former is characteristic of a resilient system and the latter of one that is less resilient. Rigid physical or institutional environments can restrict the social actors’ ability to create a sustainable

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7 Ibid.
relationship. Looking at this through the RAT theory lens, this SES would be characterized as having low adaptability because the manager’s capacity to influence the system is restricted by the conditions.

The socio-ecological scholarship highlights a noteworthy distinction. Although the SES components are coupled, linked, and interdependent, they are not equal in capabilities. The fundamental difference is the power of cognition that gives the human system the ability to reflect on memory and to act, proactively and intentionally, in anticipation of the expected effect of environmental changes (Wuethrich 2002: 35). This is the source of the social dominance discussed in Walker et al. (2004). Along with cognition, humans have cognitive biases that act as filters through which information is processed. The effect of cognitive biases will be discussed further in both the Urban Policy Learning section of this Literature Review as well as during the discussion on risk tolerance in the Research Design.

In their study Klein, Nicholls, and Thomalla explore the value and utility of the concept of resilience for coastal megacities managing hazards and reducing risk. Specifically, they evaluate strategies of anticipatory adaptation that are aimed at reducing a city’s vulnerability to weather hazards. They identify three approaches to risk reduction as: 1) choosing change in land use and relocation of exposed populations, 2) reducing losses by either preventing hazardous events, such as flooding, or reducing its impact, and 3) accepting losses by sharing (e.g., insurance) or bearing the costs (Klein, Nicholls, and Thomalla 2003: 107). The first approach of choosing change is a robust adaptation strategy, especially for port cities built in low-lying and, often, deltaic locations. A complete relocation to higher, dryer ground represents a substantial investment, which the authors judge to be the most politically and economically difficult approach for megacities. The second approach comprises primarily infrastructure adjustments, which can be maladaptive in their shortsightedness and the false sense of security they create that perpetuates a destructive cycle of new growth on unsuitable land. However, many cities have evolved using this approach. In the authors’ opinions, cities usually have a bias toward loss reduction because of the large populations and high economic values (Klein, Nicholls, and Thomalla 2003: 108). The third approach, accepting losses, essentially maintains the social status quo in a dynamic and increasingly hazardous environmental situation. These approaches are the foundation of a typology of adaptation approaches and options.
developed in chapter three and used throughout the analyses of case cities in chapters four through seven.

The authors’ quest to evaluate whether resilience is a desirable attribute of megacities and, if so, whether resiliency inversely correlates with vulnerability to weather-related hazards, led them to conclude the affirmative—with caveats. The capacity for learning and adaptation, which is a key characteristic of resilience, is necessary, and vulnerability in a social system is reduced when that system is characterized by equity (Klein, Nicholls, and Thomalla 2003: 115). Their point on equity is that the resilience of the most vulnerable population in a city is the measure of that city’s vulnerability—the weakest-link-in-a-chain theory. Development studies emphasize the responsibility of cities to adopt adaptation strategies that prioritize livelihood resilience, which is the “capacity of all people across generations to sustain and improve their livelihood opportunities and well-being despite environmental, economic, social, and political disturbances” (Tanner et al. 2014: 23). This aligns with the value that Stokols placed on moral capital in a resilient system (Stokols, Lejano, and Hipp 2013: 7). Moral capital is distinct from social capital in that it is based on ethical grounds, rather than being based on social organization.

Social capital, “the networks and resources available to people because of their connections,” (Aldrich 2012: 2) has been found to play a prominent role in community resilience both to disturbances and in post-disaster recovery. In the insightful case study of Chicago’s 1995 heat wave, the detrimental effects of social and ecological inequalities on the ability of residents to survive extreme weather was analyzed (Klinenberg 2002). Seven hundred and thirty nine deaths in a few weeks of sweltering summer temperatures in a global city in the global north is almost unheard of. In fact, the tragedy was literally unheard of because the media did not report on it to the extent they cover a tsunami, earthquake, or other abrupt extreme weather event.

The pattern of the death tolls by neighborhood led to Klinenberg’s key finding that strong social capital at the community level was the single factor that reduced the level of vulnerability and saved lives. In a comparison between two neighborhoods that were equally neglected by Chicago’s demographically discriminatory social welfare programs, the tight cohesion among the Latino Little Village kept the elderly from dying alone. This was not the case in the neighboring, yet socially-fractured, economically-abandoned, and
predominately African-American community. The connections among community members and between community members and others outside of the neighborhood provided the life-saving resources needed. Those neighborhoods that lacked the cohesion to help themselves were not offered a lifeline from outside. The city failed in their role of governing. It was a failure of monitoring, implementing programs, and adapting to the dynamic changes in the environment to protect the most vulnerable of their population.

Post-disaster recovery provides another perspective from which to evaluate the necessity of social capital in community resilience, this time during the reorganization phase of the adaptive cycle rather than the release phase when the disaster is taking place (e.g., Chicago’s heat wave). Aldrich (2012) finds that social capital facilitates recovery from a disaster at the community level more than other variables. His case studies all involved abrupt natural disasters, such as earthquakes, tsunamis, and hurricanes. He compared two Japanese cities, a plethora of Asian communities inundated by the Indian Ocean tsunami, and the Hurricane Katrina-stricken Gulf Coast communities—his findings are cross-cultural. Aldrich brings in the nuance of dimensions of social capital by distinguishing *bonding*, within a village; *bridging*, linking a village to external agencies; and *linking*, which adds a longer reach and vertical dimension to the networking (Aldrich 2012: 31-33). Combinations of social capital are better, and more connections are better, but there is a negative side to social capital, which Aldrich describes as its Janus-faced nature. It is not a public good and those not in the network, or not connected, may be excluded as resources attained by one group can be at the expense of the other group.

Klinenberg and Aldrich each offered recommendations to correct the deficit of community level social capital. Klinenberg looked to institutionalizing a public safety net and saw a role for city managers in identifying vulnerable populations and then providing them with needed social welfare services. Aldrich and his team in Japan defined a sequential process of a private-public effort (Kiyota et al. 2015) that is predominately internal to the community, but can include an external third party. This process contributes to a theory of change from vulnerability to resilience. The homegrown social capital approach (Kiyota et al. 2015) builds resilience while the government augmented social capital (Klinenberg 2002) reduces vulnerability.
The logical next step is to examine the inter-linkages of the concepts of resilience, adaptive governance (AG) and disaster risk reduction to determine how best to proactively reduce the risk of harm from increasingly probable natural hazards. In their study, Djalante, Holley, and Thomalla (2011: 4) characterize AG as polycentric with multilayered institutions, participatory and collaborative, self-organized and networked, with a high degree of learning and innovation. Analyzing the tradeoffs and benefits that result from implementing these characteristics in cases of natural disaster they find that AG improves resilience, which contributes to reducing the risk of disasters (Djalante, Holley, and Thomalla 2011: 10-11). Learning from experiences and innovation proves to be an especially potent action.

As was the case with Klinenberg and Aldrich’s findings, Béné et al. 2012, decouples vulnerability and poverty, terms that are inherently related connotations of each other. Poverty status is less important as an indicator of resilience than those factors that contribute to community preparedness and a capacity to recover. Béné et al. discuss the benefits and limitations of using the concept of resilience in social science. The advantages include its systems approach that looks at covariance, such as climate-related shocks and economic crises that simultaneously affect communities; and multi-scalar processes that affect people and their environment and feedback dynamics: local-to-global, rural-to-urban, trans-boundary (Béné et al. 2012: 11-12). The fundamental limitation is applying a concept that originated in ecology to the context of social systems, a shortcoming that has been voiced elsewhere in the literature. Specifically, resilience does not consider issues of agency and power and the relationships and decisions of humans exercising those influences within a system. Individual motivations, actions, and inactions are lost, or veiled, in the system (Béné et al. 2012: 12).

In contrast, while Miller’s study acknowledges the differences in how physical and social scientists approach SES analysis, it builds the case for strong convergence (Miller et al. 2010). Common ground is needed to bridge differences and enable coproduction of new knowledge for collaborative action. The two fundamental concepts for ecology and sociology are resilience and vulnerability, respectively. Without nuanced understanding they appear the antithesis of each other, yet they are not. Reducing one’s vulnerability encompasses issues of exposure, hazard, and risk, which do not necessarily increase one’s
resilience. While ecologists ask “The resilience of what? To what? For whom?”, sociologists question “Who defines what acceptable levels of vulnerability might be, and for whom, and how such questions are addressed?” (Miller et al. 2010: 6). Both perspectives acknowledge the dynamic and interdependent nature of the context and imply the importance of the process of adapting. A finding of the Miller study that evaluated myriad analytical concepts for convergence with resilience and vulnerability theories cited adaptation as complementary. The Adaptive Management and Learning analytical concepts are each considered to be “jointly evolving” (Miller et al. 2010: 8-9).

The Resilience and Panarchy literatures share some of the limitation of the SES literature in that there is extensive application to resource management in small ecosystems, which is not relevant to my study of cities adapting to climate change. However, the multi-scalar and cross-temporal aspects of Panarchy are promising. The concept of resilience has migrated to social studies and has been used in case studies of cities during and after extreme weather events. The criticism that resonates is that resilience does not consider issues of agency and power and the relationships and decisions of actors exercising those influences for their benefit in a system. Bahadur, Ibrahim, and Tanner (2013) point out in their literature review of resilience that case studies are needed to explore this shortcoming. This study uses case studies and focuses on adaptation strategies as a measure of resilience; thus, it will contribute to a gap in the research.

**Transnationalism and Climate Change Governance**

The adaptive management and learning theories discussion provides a good point to shift the literature review to another phenomenon of globalization, transnationalism, to address my third question: *How does TCN participation influence a city’s adaptation to climate change?* Do TCNs perform governing functions? Do climate-focused city networks exhibit those characteristics of polycentric governance deemed effective in addressing climate issues, such as self-organizing, rule-setting, and enforcing with a capacity for collective action at the local level? Historically TCNs have focused on mitigation measures to reduce GHG emissions and decrease the public bad of pollution and global warming.
How does this compare with adaptation climate action? This section of the review looks to the literature on transnationalism and climate change governance to answer these questions and identify factors, conditions, and theories relevant to my study. First the governance questions will be addressed and then the mechanisms used by TCNs to influence cities will be examined.

The increased connectedness in communications and transportation that “flattened” the world, as Friedman (2007) argued, also flattened the world order. The access to information and powerful agents that was formerly the exclusive domain of national political leaders was now open to non-state actors (NSAs) who used their new unconstrained voices to influence decisions. The nature of interactions between states and NSAs, the influence they had on each other, and the influence each had in the international domain was the focus of Risse-Kappen’s (1995) argument that transnational relations were back in international relations (IR). He wanted to shift the debate away from which actors were more powerful and explore the interactions, processes, and relationships of the evolving network of horizontal, trans-boundary networks that characterized the political arena.

Transnational governance is defined as “networks operating in the transnational sphere authoritatively steering constituents toward public goals” (Bulkeley et al. 2014: 56 references Andonova, Betsill, and Bulkeley 2009). It is a distinct form of global governance in which public and private actors interact across national borders and political jurisdictions.

Transnationalism is not limited to IR or International Political Economy (IPE), however, as the connectedness of globalization also empowered social movements. Global civil activists, myriad governmental and non-governmental organizations, private agencies and public sub-state actors collaborated on shared issues in informal and flexible arrangements. New pathways and multiple mechanisms for influence on global politics emerged in this multilevel and multicentric governance arena (Toly 2008: 351). To create order out of the amorphous phenomenon, Tarrow (2001) differentiated transnational actions by their motivation, methodology, objectives, and duration of existence. He distinguished between: international non-governmental organizations (INGOs), transnational social movements, and transnational advocacy networks (TANs). Tarrow
explains that social movements are harder to form and maintain and have different relations to states and international institutions than the latter two, which had more in common with each other and generally enjoyed better relations with state and international level organizations.

TANs are the focus of Keck and Sikkink’s (1998) book that dove into networks organized around issues of shared value to its members, which then foster and accelerate growth in transnational relations. They describe networks in this context as communication structures employed by NSAs to bridge the divide between international and national realms in the accomplishment of a mission. Networks are “forms of organizations characterized by voluntary, reciprocal, and horizontal patterns of communication and exchange” (Keck and Sikkink 1998: 91). Transnational networks are complex, embodying both structure, patterns of interactions among organization and individuals, and actors, with an agency greater than the sum of its components. The latter point was also Acuto’s (2013a) conclusion in his analysis of TCNs viewed through the lens of the Actor-Network Theory. As with a TAN, TCNs have gone outside of the state to bring pressure back on the state from both the state and international level. They saw a blockage and broke through it using collective action and different mechanisms.

Climate change is one of the issues around which transnational networks form. The emergence of transnational climate change governance (TCCG) is accredited to globalization’s empowerment of NSAs as well as the failure of states to reach an international agreement of effective climate action (Bulkeley et al. 2014, Acuto 2013a, Ostrom 2010, Van der Pluijm and Melissen 2007). In the absence of national leadership, cities and other NSAs reorganized to fill a governance gap in response to the climate change problem (Bulkeley et al. 2014: 164). Whether the new TCCG networks complement or provide an alternative to multilateral climate governance, then, is a question worth addressing.

Bäckstrand’s contribution to this question was to evaluate the democratic legitimacy of transnational governance based on the “accountability record of the various climate partnerships in terms of transparency, monitoring mechanisms, and representation of stakeholders” (Bäckstrand 2008: 74). After all, if networks are not democratically legitimate, how can they be considered a viable new tool of global governance? She
categorized transnational climate change networks based on the type of actor and distinguished networks as public, private (i.e., NGOs and corporations), or somewhere in between—a hybrid mix of government and private organizations. They lay along a continuum of types of actors between public and private endpoints. This proved useful in numerous studies (Bäckstrand 2008; Andonova, Betsill, and Bulkeley 2009; and Bulkeley et al. 2014).

This actor-type criterion was paired with the criterion of the primary function performed by the network: information sharing, capacity building and implementation, and rule setting, to build a typology of TCCG to identify patterns (Andonova, Betsill, and Bulkeley 2007: 5-6). Many patterns were not surprisingly in that the nature of the network determined their choice of mechanisms. For example, all three types used capacity building and implementation to steer their constituents toward public (governance) goals of climate action. However, public and public-actor-heavy hybrid networks were stronger in rule setting whereas no rule setting was observed in the purely private-private networks. This domination of rule setting by public networks was interpreted as an unwillingness of states to contract out this authority (Bäckstrand 2008: 78). Private and hybrid networks emphasized information sharing.

Bäckstrand’s analysis of accountability found that the multilateral hybrid partnerships had the strongest accountability record, making them the most democratic form of multilateralism. The private networks self-regulated, and the public networks operated outside the purview of the United Nations (UN) and were led by industrialized states and their corporate sponsors (Bäckstrand 2008: 99-100). The conclusion drawn is that hybrid networks are the most accountable and, thus, the most legitimate form of the three types of networked governance.

This typology framed a database of 60 initiatives built by Bulkeley et al. (2014), to represent the TCCG phenomenon as a whole and analyze the aggregated data through three lenses: agency-based, social and system dynamics, and critical political theory. These analytical perspectives influenced drawing different conclusions regarding the potential effectiveness of TCCG in addressing climate change issues compared to the effectiveness of traditional governance structures. From an agency-based perspective, TCCG is an improvement because it enhances inclusivity in that a wider range of actors can pursue
interests. However, their opinion is that TCCG has not yet filled the governance gap. The social and system dynamics’ perspective applauds TCG’s potential for wide-scale transformation of the governance system. Lastly, critical political theorists consider TCCG an extension of neo-liberal patterns of governance most strongly influenced by established interests, thus they see little chance for transformation away from existing forms of political economy and state strategy. Most critically, TCCG may function as “greenwash” (Bulkeley et al. 2014: 170).

A recurring conclusion in the literature is that TCCG is a mode of governance as much as it is a collection of individual initiatives: a mode of governance that is networked, decentralized, self-organized and often simultaneously public and private, global, and local (Bulkeley 2014: 156). As a *complementary* mode of global governance TCCG fulfills a critical role in addressing the collective action problem of global warming. However, it is not an effective alternative. Global policies are necessary, although not sufficient, and polycentric governance of initiatives at multiple levels spurs national and international regimes to action (Ostrom 2012: 366).

Specifically to the role of cities, their influence as individual actors in global politics and governance as well as their enhanced power through their collective action in networks, is examined in the literature. Acuto (2013b) argues that global cities have more nuanced analyses of world politics, a more multi-scalar image of global governance, and fill a strategic diplomatic position on global problems such as climate change. Van der Pluijm and Melissen (2007: 19) identify five functions of city diplomacy as: facilitating communications, negotiating agreements, gathering information, preventing conflicts, and symbolizing the existence of an international society. In order for cities working together as a collective to be diplomatically effective they must speak with one voice, which entails internally aligning their interests and goals to one another’s (Van der Pluijm and Melissen 2007: 31). Cities may align on issues with other cities, on which they may or may not align with their host nations. The effect on cities of cities working collectively, in and of itself, may persuade states to reconsider their positions on climate action. Together, cities have a great deal more influence than they would separately (Toly 2008: 352). As Acuto concludes, cities working horizontally, vertically, and as a network take Putnam’s two-level
game to all tiers by expanding the multiple and intertwined scalar spaces of global governance (2013b: 164).

The TCN literature as a subset of political science literature exemplifies the criticisms of both Javelin and Keohane in that there is a deficit in the literature on adaptation climate action. This deficit, in fairness, reflects the cities and TCNs earlier focus on mitigation climate action. The more recent inclusion of adaptation to SLR by delta cities, however, does not change how TCNs influence cities and their decision-making processes. In fact, this literature most closely supports my study of how climate change affects city governance; it does so via TCNs.

**Urban Policy Learning**

The next step is to examine the role of a TCN in a city's learning process. The global governance literature suggests that networks facilitate learning through four mechanisms: the sharing of information about effective policies; demonstration effects and mimesis; the reconfiguration of incentives and payoffs in collective action problems; and through the social construction of norms that regulate risky practices. Lee and van de Meene (2012) unpack the learning process into three necessary sequential stages: information seeking, adoption, and policy change. In the context of a city adapting to climate change this is an iterative and ongoing process that is more effective in a tightly coupled system.

In their case study of a prominent TCN, C40 Cities Climate Leadership Group (C40 Cities), Lee and van de Meene’s findings are that this TCN was a catalyst for urban policy learning on climate action. Their network-of-networks structure facilitated horizontal city-to-city diffusion of best practices for both mitigation and adaptation programs and policies. This sharing of information between information sources and information seekers collaborating toward shared goals occurs in the first stage of learning. Demonstration effects and mimesis occurred during all three stages of learning through transparent observation, by serving as test beds, through their associative status of "greening," and as a

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city-network model. The reconfiguration of incentives and payoffs was facilitated through strategic partnerships that bridge the local to international levels and results in greater cooperation. This mechanism occurred during progression from the second to the third stages of learning. Lastly, the social construction of norms also occurred during the second and third stages of the learning process.

In C40 Cities, there is homogeneity of beliefs regarding the threat posed by climate change, a bias toward action, and a widespread practice of framing the situation in economic, rather than environmental terms, because it is politically advantageous. Toly found in his study into the role of transnational municipal networks that cities that engaged collectively in climate action are norm entrepreneurs, and, as such, become mechanisms for change both domestically and globally (2008: 352).

In combination these four learning mechanisms provide opportunities for cities that participate in a TCN that other cities may not have access to, which suggests there is an advantage to network membership for cities predisposed to climate action. The advantage is access to an established process of learning that leads to policy change and climate action.

Rather than portraying this in an overly positive light, however, it is important to note a phenomenon that strongly influences city decision makers—cognitive bias. C40 Cities cites their “bias toward action” as bragging rights in contrast to national inaction caused by both domestic politics and scale. Be that as it may, there are other biases, which are not advertised, that may blind decision makers to alternatives and lead cities to adopt maladaptive strategies. Although primarily at a subconscious level, biases act as filters through which information is processed. Lee and van de Meene (2012) see this process take place in the adoption stage of the policy learning process. The decision makers have gathered information from external sources, which they compare to their experiences, beliefs, and needs. If the new knowledge fits, albeit with a little modification, then adoption takes place and the process toward policy change proceeds. If not, the new information is discarded and policy change does not occur at that time.

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9 Robert Chisholm, “Progress and Mimesis: Political Ideas, Imitation, and Development,” *New England Journal of Political Science* 1, no. 2 (Spring 2006). This phenomenon of the status of association with a model or process is documented in other political organizations as well.
Conclusion

The SES, Resilience, and Panarchy concepts provide holistic paradigms for understanding the context of my research questions and examining how social actors perceive, react to, and proactively adapt to climate change related hazards in their city environment. The latter two concepts do so more than the SES concept. They are models borne of the systems approach to analyzing complex adaptive systems characterized by dynamic interdependence and the emergence of new behavior. Although the Panarchy model has not been scaled to global cities with high rates of urbanization, industrialization, resource extraction, and pollution in a turbulent environment, the concept appears to be a useful framework for analyzing decision making.

My focus is on whether and how the cities adapt. The dynamic nature of the SES makes adaptation an ongoing process of observing, changing behavior, monitoring the effects, learning and adjusting, and then repeating the cycle. The urban policy learning process can be neatly woven into the Panarchy four-stage adaptation cycle. In general this is how it could work. The reorganization stage would entail large-scale learning as the social component recovers from the release stage caused by a major environmental disturbance. As the system shifts from reorganization into the exploitation stage the learning process narrows and decreases in scale as options are ruled out and connections are made to adopt policies deemed most appropriate. The conservation stage of adaptation has the smallest scale of learning because the focus is on incremental efficiencies rather than large decisive change.

This is a single issue, single city example. In reality the process is embedded with myriad others in a city that is nested between smaller communities, their nation-state, and connected transnationally with other cities. These other levels of political and economic activity affect the context of the city’s learning process because it manifests as input in their information gathering process. The nested renewal cycles in the Panarchy framework that cross scales and time facilitate accommodating this context. Other cities could be represented similarly and connected to each other through the TCN, which would bring in connections with other NSAs. TCNs can speed up the learning process and affect the
trajectory of city adaptation decisions. The TCCG literature makes it clear that TCNs will influence climate change action, and emphasizes that the influence can be positive or negative.

Evaluating the TCN effect on a city requires analysis of the characteristics of the decision-making processes and programs rather than evaluating outcomes of program implementation. That is due to the anticipatory and proactive nature of adaptation as a phenomenon that produces a negative outcome (i.e., reduces the impact of hazards). The preponderance of the SES and Resilience literature agrees that conditions of redundancy, diversity, inclusivity, risk spreading, reciprocity, reputation, trust, autonomy, communications, and institutionalization are conducive to appropriate adaptation that increases system resilience. When these factors are missing, a SES will not be as resilient as when they are present. These factors form the foundation for evaluating whether a city’s decision-making process for adopting an adaptation strategy is effective or maladaptive. Operationalizing these variables for application at the city level is a process that is on-going in practice and is discussed in detail in chapter three.

From the perspective of theory, if a city’s adaptation process fits the profile of resilience as described in the literature, it will likely support the behavioral theory of collective action. If, on the other hand, the process is maladaptive, the social and ecological components of the SES will be in an unsustainable relationship. There is a high probability that maladaptive policies are the outcome of dominating political and economic actors whose behavior reflects rational-choice-theory decisions to maximize short-term relative gain.

The role of TCNs may reflect the more positive predictions of the agency-based, and social and system dynamics analysts who hail the increased inclusivity of diverse actors. If the TCNs’ external influence on a city’s stakeholders encourages development of processes characterized by the attributes that produce resilience, then TCNs will be an effective form of self-organizing, polycentric governance of climate action. This would be a manifestation of collective action scaled up to a much larger level than the more familiar territory of common pool resource researchers.

Alternately, TCNs may prove to be an extension of neo-liberal patterns of governance most strongly influenced by established political and economic interests, as the
critical political theorists warn. Rather than enhancing local adaptation through the infusion of lessons learned, TCNs may facilitate extending the reach, to other cities, of elite stakeholders engaging in transactions to set the agenda for their short-term gain at the expense of the information-seeking city. This would be a dysfunctional process that does not strengthen the social-ecological relationship for the city. It has the potential of reinforcing the Global North–Global South divide and would then relegate TCNs to being a scaled down, “mini-me” version of IR, rather than a transformational form of governance for climate action.

Lastly, the vast majority of literature and TCN activity is on mitigation climate action. Reducing GHG emissions to lessen the polluting cause of global warming is the common good around which cities rallied after nations failed to act collectively. Adaptation climate action has been sidelined because it is complex, context specific, difficult to measure, and it does not address the problem of climate change in the long term. The data available on adaptation is limited. This makes research more challenging, but also makes it more important and the dearth of work by political scientists to date has generated a call to action by those recognizing the significance of this form of climate action, as detailed in chapter one.

From here we move into my research design, chapter three, which has five main components. They are: the Panarchy framework, case study methodology, operationalization of the dependent and independent variables, overview of climate action and development of an adaptation typology, and case selection.
CHAPTER 3

RESEARCH DESIGN

The research design is laid out in five sections. It begins with the Framework section and explains how the Panarchy concept is well-suited for an analysis of nested decision making about adaptation in a complex adaptive system. The second section, Empirics: Case Study Comparison, covers the methodology of using a natural experiment, a comparison of four case studies, certain selection criteria, and a bounded timeframe for the study. Section three, Factors, identifies, defines, and operationalizes the independent and dependent variables and specifies which of those factors that are controlled for in the case selection. The fourth section defines climate action and distinguishes mitigation from adaptation. It includes development of a typology of adaptation strategies that is used to operationalize the dependent variable—resilience. The fifth and final section of this chapter is a brief discussion on case selection based on a wide variation of the dependent variable.

Framework

In scientific terms this study evaluates the adaptation process of the socio-economic component (i.e., a city) of the SES to the dynamics of its hydro-geological component (i.e., SLR-related hazards). How does a city react to recurrent flooding or a severe storm? When faced with a strong environmental disturbance that threatens a city’s ability to continue its primary functions, what decisions will the actors make? Which factors influence whether, when, and how a city adapts? The challenge lies in distinguishing which actors, conditions, and relationships are the most influential at any given point in time. And, as importantly, what are their interactions, relationships, and processes? What trade-offs are they willing to make? In order to accomplish this I make some assumptions, describe the multiplicity of

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1 S.F. Balica, N. G. Wright, and F. van der Meulen, “A Flood Vulnerability Index for Coastal Cities and its use in Assessing Climate Change Impacts.” Natural Hazards 64, (16 June 2012): 77.
dimensions involved, and apply the Panarchy concept as a framework to examine and better understand the adaptation process.

First, this study assumes actors (i.e., stakeholders with a vested interest in the city) make basically rational decisions although with limited information and a high degree of uncertainly, and do so in the social context of a collective action situation. Cities have grown up during a time of relative climate stability and predictability and became epicenters of social, economic, and cultural activity characterized by specialization, optimization, efficiency, and economies of scale. That is no longer the case, however, because global warming has moved us outside the familiar range of climate variability. Weather forecasters use historical data to predict weather probabilities, but we are outside of their model limits.² Too many of the variables are in a state of flux and it is difficult to discern whether and what new patterns are emerging. Weather events are expected to become more extreme and extreme weather will become more common.

Climate instability adds a factor of uncertainty that must now be taken into consideration by urban planners, businesses, governments, and citizens. These city stakeholders need to broaden the range of conditions in which the city will function in light of more variable environment factors because they have a vested interest in sustainability of the city. The stakeholders are interdependent, engage in transactions iteratively, and develop relationships through collaboration. In doing so they build conditions of reputation, reciprocity, and trust while focusing on a long-term objective to optimize future rewards, both individually and collectively. Thus, although the hazards associated with the changing climate alter the specific conditions in which decisions are made, stakeholders must continue to work collectively and rationally to adapt to these new and fluctuating conditions and thrive in their city.

Second, there is a multiplicity of dimensions to consider both at the city level, which is the focus of this study, and beyond. There is vertical interaction between public and private actors at the city, regional, state, national, and international levels. There is also the horizontal transnational interaction between distant cities via the TCN. The temporal dimension encompasses cumulative social and economic effects of environmental hazards

over time. The planning timeline to implement engineered and behavioral measures to mitigate future risk is another consideration. These spatial and temporal dimensions must be viewed holistically as they affect the decision and adaptation processes being examined.

After reviewing the literature, the Panarchy concept is the better fit for enabling multi-dimensional process tracing. “Panarchy is a conceptual framework to account for the dual, and seemingly contradictory, characteristics of all complex systems—stability and change. It is an integrative framework, bringing together economic, ecological, and social models of change and stability to account for the complex interactions among these different areas, and different scale levels.” Panarchy is an “attempt to connect ecosystem functioning with economic activities and human institutions for managing the relation between the two.”

Its adaptive cycle is a suitable framework to represent the iterative, interactive, nested, scalar and temporal aspects of urban planning for climate risk mitigation. Its application to this study is to aid in teasing out independent and intervening variables that cause change in the dependent variable—resilience—via the adaptive cycle. Figure 3.1 illustrates the relationship between the four stages of the adaptive cycle: Conservation, Release, Reorganization, and Exploitation.

![Figure 3.1](Image)

Figure 3.1. Four-stage adaptive cycle: conservation, release, reorganization, and exploitation.

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Take an example of a coastal city recovering from a significant storm that caused widespread flooding to illustrate the stages of the adaptive cycle and how different actors affect decisions. The storm occurs at the peak of the conservation phase when the socio-economic component is at its most connected, most efficient, least flexible, and most vulnerable. The intensity of the storm is greater than usual and the extensive damage exposes the city’s vulnerability. The impact of the storm, an action from the environmental component of the SES, is a shock that forces a reaction from the socio-economic component of the SES and initiates the release phase. The release stage encompasses the experience of the storm, the flooding, human and infrastructure triage, in-depth damage assessment, and disaster recovery. The shock severs connections, breaks down institutions, and forces the community to work very hard and inefficiently in slowing the destruction that is the release phase. A city’s primary objective for adaptation planning should be mitigating storm damage by having redundant utility, transportation, and communications systems in place and having evacuation and resident catchment plans that are effective and familiar to residents.

The next stage is reorganization, the phase during which the city’s stakeholders gather information, evaluate options, assess available resources, and adjust their adaptation policies to reduce the risk of future hazards. Once a mix of engineering and social measures is decided upon and financed, the city enters the exploitation phase. This is when land use is modified, vulnerable populations are relocated, early warning systems are installed, evacuation plans are promulgated and practiced, protective barriers are built, and infrastructure is waterproofed to the extent practical. If the adaptation measures that are taken are able to withstand future storms and flooding, it is unlikely for both political and economic reasons that further safeguards will be adopted. The city then settles into the conservation phase where efficiencies maximize economic and social benefits.

To avoid complacency and the resultant increase in vulnerability, however, the city can continue monitoring the effectiveness of the built and procedural adaptation measures, as well as the hazard risk. If a flaw in the engineered measure or a gap in coverage in the social adaptation procedures is detected, or if new data indicates a greater risk of hazard, then a resilient city would initiate a proportional adjustment to maintain the same standard of protection. Proportional adjustments made frequently and proactively create a
behavioral pattern of adaptation climate action. These smaller and faster adaptation actions taking place alongside longer-term adaptation tighten the feedback loop between the society and its natural environment. This pattern of behavior is characteristic of a sustainable relationship and a resilient SES.

Figure 3.2 illustrates this nested nature of a city’s adaptive cycle. It depicts the relationship between the large and slow adaptive response to the catastrophic event and the scaled down adaptation to the smaller disruptions. Resilience theory asserts that systems that undergo more frequent adaptations are more resilient because their adaptive process never ends. They remain more flexible than highly connected societies bound by rigid institutions, which is characteristic of the conservation stage of adaptation.

Cities deal with numerous issues simultaneously, some are routine while others are crises. Climate change alone can pose multiple SLR-rise related threats to a coastal city in the form of more extreme tides, storm surge, or both, and all must be addressed at the same time. Figure 3.2 helps visualize this ongoing adaptation process of a city seeking greater resilience.

There are myriad factors that interact and influence a city’s adaptation capability (i.e., resilience), however, for this study, six key actors and conditions are of interest. They will be explained in depth later in this chapter, but a brief overview follows. First, hazard events are the most direct causal factors of adaptation. The intensity, frequency and type of hazard evoke responses from a city that vary

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Figure 3.2. Panarchy, a heuristic model of nested adaptive renewal cycles emphasizing cross scale interplay.

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5 Figure 3.2 source: Resilience Alliance website [https://www.resalliance.org/panarchy](https://www.resalliance.org/panarchy) (accessed January 2016). This colorized version of the Panarchy model is based on the original image in Panarchy: Understanding Transformations in Human and Natural Systems, eds. Lance H. Gunderson and C. S. Holling, (Washington, D.C.: Island Press, 2002): Figure 3-10, p. 75. See Appendix A – Permissions.
proportionately, or not, depending on other factors. In general, as recurrent flooding and storm surge undermine a city’s infrastructure, threaten the safety of its population, and diminish its ability to function effectively, the stakeholders decide to either allocate resources for protection or change behavior to reduce exposure. Actual hazard events force recovery and motivate adaptation while the city’s perception of the risk of future hazard events prompts proactive adjustments.

Second, do the city’s politicians have the authority to make decisions that are in the best interest of the local stakeholders? If the federation structure is strongly decentralized with authority and responsibility controlled at the state and municipal level, then the mayor or city manager is empowered positionally with the authority to govern locally. This can be positive or negative depending on conditions, but, in general, the literature on polycentric governance of common pool resources suggests local governance is more effective than distant control.

Third, the financial capacity of the city to allocate resources to build engineered structural protection will influence when and how adaptation occurs. Financing can be public or a public-private mix, and may be self-generated or brought in from stakeholders at higher scales. Federal government funding, or grants from philanthropic or international organizations, or foreign direct investment are all financing options.

Fourth, membership in a TCN of cities that face the same hazard and share common vulnerabilities and constraints is advantageous to cities contemplating options. C40 Cities membership is an intervening variable that facilitates faster access to information about adaptation options, financing opportunities, and best business practices and this accelerates the learning process during the reorganization phase.

The fifth factor that influences a city’s resilience is considered by the literature to be a cultural one that may or may not correlate with financial resources. Risk tolerance is a measure of one’s ability or willingness to accept loss in the anticipation of gain in situations of uncertainty. It differs among individuals, and, in the aggregate, this is an intervening variable that can temper or exaggerate the adaptive response to a hazard.

Lastly, special interest groups as actors that have a strong incentive to extract a short-term benefit from a city without having the same vested interest in its longer-term sustainability, as do local stakeholders, deserve scrutiny. Their influence can retard a city’s
willingness to change behavior that upsets the status quo, from which they benefit disproportionately.

These factors interact with each other and some are the consequence of yet other factors—risk tolerance, for example—which makes isolation of causal effects a complicated matter. However, this research design will control for a couple of variables in an attempt to detect causation, as is discussed in the following section.

**Empirics: Case Study Comparison**

**Natural Experiment**

The unit analysis is at the city level, and the objects of observation are four global port cities and their collaboration—or lack thereof—through a TCN to adopt adaptation policies to increase their resilience to SLR-related hazards. In the truest interpretation of the description, this is a natural experiment with Mother Nature providing the stimulus to vary the factors to be observed. The nature of the study limits our ability to control factors. Cities are complex adaptive systems within a SES during a time of unprecedented environmental instability. Also, the application of resilience thinking in the context of social science (i.e., cities) is relatively new and indices are just being developed now to measure and compare levels of resilience. There is not an established ranking of cities by their resilience to SLR-related hazards, which means my dependent variable cannot be measured objectively or with accuracy. That said, the intent of this study is to choose cities with a wide variance in their adaptation policies to SLR and then identify the influential factors and trace the decision-making process that led to their adoption of antithetical policies.

**Why Case Studies?**

The case study methodology is the best fit for analyses of the actors, conditions, and processes involved in the decision making of cities in adopting adaptation policies because
it facilitates theory testing and building, process tracing, and comparisons.\textsuperscript{6} This is how it will be utilized.

First, the theory that C40 Cities is a network that contributes positively to its member cities’ ability to take effective climate action will be tested. This theory is based on the claim by the network itself and its members, as well as findings in the literature that transnational climate change governance is a viable alternative, at best, or a necessary complement, at least, to international agreement on climate action. This study will evaluate how well the network does in the specific case of adaptation by global port cities to SLR-related flooding. Does C40 Cities, as an intervening variable, influence cities to adopt appropriate adaptive measures or are there other political or economic factors at work that affect the adoption of maladaptive measures? Does the connectedness of C40 Cities as an institution, with its existing structures and processes, inadvertently block innovation and novel approaches that would be ideal, rather than merely effective, for a member city?\textsuperscript{7}

If the theory is valid in these cases, the cities’ adaptation process will strengthen the resilience capacities of its people, infrastructure, organizations, and knowledge sources. This will manifest as a mix of engineered projects and social programs that reduce the vulnerability of the entire population against the threat of SLR-related flooding in the near term as well as into the future. Ideally, policies are adopted that are both economically appropriate, socially just for the vulnerable, and contribute to long term resilience rather than being economically beneficial to a few stakeholders in the short term or career enhancing to city government officials.

If a city’s adaptation policies do not meet these criteria, then the theory is proven false for this scenario. The case methodology identifies special conditions required for the theory to hold true and narrows its explanatory range. A modified or new theory can then be created that more accurately portrays C40 Cities’ influence. For example, Jakarta’s decision to build a massive barrier, the Great Garuda, to protect its Special Capital Region from the Java Sea at a cost of $50 billion is maladaptive from economic, environmental and


social perspectives. Full funding for the project had not been identified as of June 2016 and, considering the lack of domestic financial capacity—Jakarta’s GDP per capita is about $14,000 and Indonesia’s is $3,500—this is not a sound economic decision.\(^8\) The land reclamation and new construction in the bay that is required to build the barrier will destroy the coastal ecosystem, kill the near-shore fish populations, and force fishermen to sail farther to sustain their livelihoods.\(^9\) The displacement of the poorest segment of the city’s population, which lives in informal settlements, without designated resettlement land and housing is a concentrated cost borne disproportionately by that segment.

This same type of engineered adaptation measure (e.g., the Delta Works in Rotterdam and the Thames Barrier in London) is more appropriate in richer cities because key conditions varied considerably between the richer cities and Jakarta. The Dutch and English port cities had the financial wherewithal to fund the projects, a segment of the population did not rely on fishing, and no one was displaced. All three cities are members of both C40 Cities and the sub-network Connecting Delta Cities (CDC).

The incongruities between the observations and the theory provide an opportunity to modify the theory of C40 Cities’ influence on adaptation climate action or create a new theory. In fact, based on preliminary research, I have developed a number of hypotheses that this study should be able to build on or refute. Hypothesis number one: C40 Cities’ best business practices for adaptation to SLR favor hard engineered structural barriers and other protective measures that are more appropriate for wealthy cities at the expense of necessary behavioral modifications that are politically contentious. Hypothesis number two: The horizontal networking among C40 Cities’ members will partially bypass the vertical blockage at the national level, however, it may also preempt development of a more locally inclusive adaptation strategy from the bottom-up. Hypothesis number three:


Abrupt and catastrophic weather events are a necessary, although not sufficient, condition for adopting an adaptation strategy that requires either an allocation of significant financial resources or entails a significant change to land use policy. This would follow Douglass North’s theory of discontinuous change in an institution.\textsuperscript{10}

Second, process tracing “explores the chain of events or the decision-making process...” that clarify the cause-effect relationship between factors in a case.\textsuperscript{11} This aspect of case study analysis is well-suited for examining sets of activities and tasks that a city administration and other stakeholders undertake during the decision-making process. Overlaying process tracing onto the structure of the Panarchy framework should facilitate identification of the adaptive cycle stages at which TCN intervention takes place and provide insight as to whether the intervention moves the city forward toward a sustainable relationship with its environment, or if it encourages a maladaptive ‘solution’. In the earlier example, did Rotterdam unduly influence Jakarta to favor its model of adaptation over a more behaviorally oriented policy of managed retreat and revised land use policies through their collaboration within CDC? Do TCNs connect city elites who then devise solutions that concentrate benefits on certain stakeholders? Process tracing in case studies facilitates decomposition of the decision-making processes to a level more conducive to examination.

Third, the case study methodology enables the controlled comparison of cases with similar conditions and characteristics to determine which factors elicit different outcomes. To accommodate this analysis a few independent variables will be controlled for in the selection of cities with diverse dependent variables and those independent variables that are not controlled will be examined to pinpoint their influence. This will narrow the range of causal factors of the four varied outcomes, which is in line with the method of differences. This method also enables the comparison of similarities and differences internationally. For example, comparing cities, from different countries, that have a similar primary function, geophysical characteristics, and SLR-related hazard experience and future risk facilitates examination of the role of money and politics by focusing on federal government structure, financial capacities, risk tolerance, the role of special interest

\textsuperscript{10} Douglass C. North, \textit{Institutions, Institutional Change and Economic Performance} (Cambridge: Cambridge University Press, 1990), 89.
\textsuperscript{11} Van Evera, \textit{Guide to Methods for Students of Political Science}, 64.
groups, and the different cities’ relationship with the same TCN. Specifically, this comparison aims to explain the economic and political factors that influence the level of resilience of four global port cities at high risk from SLR-related hazards.

**Case Selection Criteria and Timeframe**

Case selection is a two-phase process. First, a pool of candidates is identified based on selection criteria that control for certain characteristics and conditions of cities (i.e., independent variables). The second phase starts with this delimited pool of cities, and selects candidate cities based on a qualitative review of their adaptation strategies with the goal of obtaining a wide variance in the dependent variable (i.e., resilience). This selection methodology will enable a robust case study comparison. The data sources are secondary and are predominately from peer-reviewed literature, professional organizations and institutions, and media reporting.

The timeframe of the study focuses on the recent decade, 2005-2016, which was a period of increasingly extreme storms and SLR-related flooding that have become a growing concern for port cities. This concern also made 2005-2016 the most active time of cities working through transnational networks on climate action, including adaptation. However, historical information from the formation of the city onward that explains its relationship with the environment is also included in the study to provide an understanding of the evolution of societal behavioral patterns and the emergence of key actors and the institutionalization of their influence. These data are intended to aid analyses of any observed behavior that deviates from expectations based on rational choice theory.

In summary, this study’s intent is to trace the adaptation process of cities to hazards, examine the influence of political and economic actors and institutions, look at the effect of historical institutions, and make theories that explain when and why a city would adopt an effective or maladaptive strategy. Case studies are well-suited for the inductive process of making observations, exploring the cause and effect relationships between variables over time and across scales, tracing processes, and testing and making theories. Because of the

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12 Ibid., 64-68.
small sample size, case studies are not effective for making generalizations. This study is interested in the former rather than the latter, thus the case study methodology is used.

Factors

Dependent Variable: Resilience

As the literature review explained, resilience is a concept that originated in biology and ecology. Vulnerability is the antithesis concept, which has its roots in the social sciences. Viewing SESs holistically in the context of climate change forces a reckoning of terminology. Resilience is now used as a descriptive characteristic, alongside vulnerability, for cities and is considered useful particularly for hazard management and disaster recovery. Adoption of the resilience characteristic into social science has spurred creation of sets of metrics and indices for comparing cities’ adaptation policies. It is now considered a critical lens that is useful for viewing climate change and other dynamic forces that disturb SESs.

The first step in operationalizing resilience for this study is to define urban resilience, describe a continuum of resilience, explain a set of characteristics in the context of adaptation to climate change, and discuss an index of resilience in cities. This section draws predominantly from the Resilience literature.

Definition of Urban Resilience

First, resilience is defined thoroughly in the literature. A synthesis, categorization by level of analysis (i.e., individual, community, city, social, ecological, and physical), and a discussion of representative definitions is provided by Norris et al. 2008. This robust

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effort to thoroughly, yet parsimoniously, define a concept that originated in one science and migrated to another is viewed two ways. More definitions provide options for wider application; however, some experts in the resilience field decry the “30 years of academic analysis and debate” as disappointing in yielding a “definition so broad as to render it almost meaningless.”

Despite the disappointment of some by the lack of consensus, resilience defined as “the capacity of a system to absorb disturbance and re-organize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks,” is often cited as the best definition. It captures all properties of the concept and has broad application. However, resilience theorists emphasize the contextual nature of resilience and ask “The resilience of what? To what? For whom?”

Answers to these questions refine the definition of resilience for cities to “urban resilience is the capacity of cities (i.e., individuals, communities, institutions, businesses and systems) to survive, adapt, and thrive in the face of stress and shocks and even transform when conditions require it.” This emphasizes resilience as an ability or process, which more aptly suits the dynamic context of a complex adaptive system, rather than an outcome, which portrays a stable environment or state of equilibrium. Megacities are many things, but they are neither stable nor do they have equilibriums.

For cities facing the threat of SLR-related hazards, then, resilience is tied to the effectiveness of their adaptation process in reducing vulnerability. Effectiveness can be evaluated by asking questions along these lines. How is the process managed? What is the decision-making process and who is involved? Who is excluded? Who prioritizes the portfolio of challenges? Which stakeholder group gains and which losses from the decision among alternative courses of action (i.e., engineered structural projects or social program

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solutions)? Are the gains and losses concentrated or diffused? What about the most vulnerable populations?20

**Continuum of Resilience**

Second, most systems are resilient, more or less, and a system’s resilience to a specific hazard at any point in time will lie on a continuum. Fragile systems, which fail when faced with stressors, are least resilient. They are located at one end of the spectrum with increasing levels of resilience lying between the endpoints. The most resilient systems, which are transformative, are at the opposite end. Just beyond this scale of resilience lie anti-fragile systems; a point outside the realm for cities because they are too institutionalized, rigid, and complex to thrive in disorder.21 Cities cannot be anti-fragile.

Figure 3.3 illustrates systems on a scale of resiliency; in this study the systems are cities. Effective adaptation to a risk moves a city to the right. An example of a less resilient city is New Orleans based on the horrendous damage it suffered during Hurricane Katrina in 2005. Rebuilding it to become more resilient is ongoing.

Figure 3.3. Continuum of resilience.

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20 Lebel et al., “Governance and the Capacity to Manage Resiliency…,” 3. This study developed these questions.

21 Nassim Nicholas Taleb, *Antifragile: Things that gain from Disorder* (New York: Random House, 2012): 3-9, and 32. Talib describes antifragile as a property of systems that thrive in disorder, chaos, volatility, nonlinearity and stressors. It is the antonym of fragile, but beyond resilient and robust.
The true proof of resilience is in how well a city weathers the storm. But post-disaster recovery is the wrong time to test the effectiveness of a city’s adaptation policies. The costs are too high. Cities have limited resources (i.e., time, money, people) and need to allocate them in a manner that produces measurable improvements in resilience. Measuring resilience prior to a weather event requires identifying characteristics of a resilient city and then comparing one’s city to the ideal. Will we know a resilient city if we see one?

**Characteristics of Resilience**

Third, to answer that question we turn to the comprehensive list of characteristics Bahadur, Ibrahim, and Tanner developed from a focused literature review of resilience in the context of social, ecological, and SESs.22 Those ten characteristics are listed and briefly explained as follows:

**High diversity.** The concept of diversity originated in ecosystem management, but is now as enthusiastically applied to economic, social, and SES environments in the context of climate change. Multiple sector economies, a variety of stakeholders, alternative adaptation strategies, and a mixture of natural resources improve the resilience of the systems that rely upon them and make the socio-ecological relationship more sustainable in a highly uncertain climate.23

**Effective governance and institutions.** Since Ostrom’s and Berkes’ early work on SESs and effective management of common pool resources there has been growing consensus on the advantages of decentralized and polycentric governance. Local knowledge; stakeholder ownership; the build-up of trust, norms and networks; and increased flexibility are some of the benefits. However, over institutionalization causes rigidity and can foster power relations, which are contrary to improving resiliency.

**Acceptance of uncertainty and change.** The nature of an SES is one characterized by complexity, non-linearity, a high level of uncertainty, and continual change. Institutional structures that are flexible and redundant will be more effective in dealing with these

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22 Bahadur, Ibrahim and Tanner, “Characterising resilience,” 2013. Source of the descriptions of ten characteristics unless otherwise noted.
23 Ibid., 3. Authors cite The Rockefeller Foundation, 2009: 2, for highlighting the advantage of a diversity of planning, response and recovery activities for resilience to climate change.
characteristics in the environment. The authors note that adaptive policy-making, management, and governance in SESs are more developed in theory than in practice.

**Acknowledgement of non-equilibrium dynamics.** This property is a step beyond the previous characteristic (i.e., acceptance of uncertainty and change) in that the goal of adaptive management cannot be to return to, or *bounce back*, to a stable equilibrium. The social component that strives for stability is increasingly vulnerable to an ever-changing ecological component; stability will equate to a lack of resilience. With this realization decision makers must shift adaptation policies from attempts to control change, create stability, and return to a former state, to policies that manage the capacity of systems to cope with, adapt to, or shape change.

**Community involvement and the inclusion of local knowledge.** The literature stresses the importance of local community members being empowered to solve local issues and links local stewardship, engagement, and autonomy with increased resilience. However, there is a lack of discussion on the “political economy constraints to community resilience” and a lack of “acknowledgement of the limits of community knowledge.”

**Preparedness and planning for disturbances.** Embedding disaster preparedness plans in adaptation policies entails building in redundancies in both the physical infrastructure, when financial capacity permits, and social programs. Redundancies provide options, which account for failure in a way that mitigates the impact of a disaster. Building the adaptive capacity of communities “is an investment in agency for preparedness, planning and readiness,” which is essential for a city to be resilient regardless of the extent of engineered protection measures.

**High degree of social and economic equity.** This property is primarily concerned with the equitable and just distribution of the impact of disasters. Thus, adaptation measures, including both “hard” engineered projects and “soft” social programs, must address issues of class, gender, and accountability to fully reduce vulnerability and increase resilience.

**Robust social capital, values, and structures.** These attributes improve the resilience of a community in the context of ecosystem management (Ostrom), which

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24 Ibid., 5.
25 Ibid., 6. Authors cite Ensor 2011; Levine, Ludi, and Jones 2012.
proactively mitigates disaster, and in post-disaster recovery (Aldrich), in that recovery is quicker and fuller in neighborhoods with a higher level of social connectivity and access to social resources. Self-organizing skills, greater citizen participation, a higher degree of place attachment, and ownership of the problem are challenging to consciously increase via social programs. Especially since, as Aldrich points out, there is a negative, exclusionary side to social capital and social networks. However, if the issues of justice and equity are prioritized, the efforts to build trust and community ties enhance the effectiveness of an adaptation strategy.

**Continual and effective learning.** This is the core of the adaptive cycle of the Panarchy concept. In the reorganization stage the learning curve is quite high as new information is gathered and options are tried and evaluated. In the exploitation stage the more promising options are fully developed and others are abandoned. In the conservation stage the learning curve levels out as fine-tuning increases efficiencies. That decrease in the learning curve in an environment of change leads to increased vulnerability. A resilient organization will institutionalize processes of iterative learning, reflection, and adaptive management.

**Adoption of a cross-scalar perspective.** Resilience is built through social, political, economic, and cultural networks that reach from the local to the global scale. The vertical integration of communities is defined as “structural and functional relations of a community’s various social units to extra-community systems,” while TCNs facilitate a horizontal connection to distant communities. The authors add a cautionary note that cross-scalar ties from colonialism that ignore the issues of equity and justice can be malignant.

Many of these characteristics are complementary and when considered in aggregate they could not fail to strengthen a city’s adaptive cycle and resilience. However, as the authors note, there is no agreement on “what combinations” or “how many” of these characteristics will serve as an indicator of the level of resilience. These characteristics are more conceptual than tangible which makes measuring relative degrees of each

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26 Ibid., 8. For the definition of vertical integration the authors cite the Committee on Disaster Research in the Social Sciences of the National Research Council, 2006, p. 233.
27 Ibid., 9.
challenging. Proxies must be identified and tested in the field to develop an index against which other cities can be measured.

For example, how does one measure the level of “acceptance of uncertainty and change” in a policy-making organization? If decentralized decision making is the proxy for flexibility, which is a property of acceptance of uncertainty and change, then we can evaluate the decision-making authority of local stakeholders.\(^\text{28}\) The typology of powers that mayors have over adaptation that was developed by C40 Cities could be used as a gauge to compare the authority of a case city.\(^\text{29}\) Per their survey, 31% of the 57 participating mayors have strong power to “set vision” for adaptation, however, only 20% have strong power to “control budget.” If the case city self-reported a higher level in these two types of power than average, then a relative qualitative evaluation of more “acceptance of uncertainty and change” may be appropriate. Time spent requesting approval from a higher level of government reduces flexibility and lengthens the decision-making process. Control of the purse strings is often the clearest indication of authority.

**Index of Resilience**

Fourth, the path to building an index is being pursued by The Rockefeller Foundation. In 2012 they partnered with Arup to develop the City Resilience Framework (CRF).\(^\text{30}\) It is a tool they have made available to TCNs with which they are affiliated, such as 100 Resilient Cities (100RC) and Asian Cities Climate Change Resilience Network (ACCCRN).\(^\text{31}\) The intention is that cities will self-evaluate their processes and expend effort to improve processes that may be hindering their adaptation. Once enough cities have provided their data to the TCN, the aggregate data will form an index by which other cities can then gauge their resilience.

\(^\text{28}\) Ibid., 4. Rockefeller Foundation’s ACCCRN has made inroads through their City Resilience Index in the measurement of characteristics.
The CRF is based on seven qualities of resilient cities: reflective, robust, redundant, flexible, resourceful, inclusive, and integrated. Note that these seven qualities and Bahadur, Ibrahim and Tanner’s ten characteristics are two methods of comprehensively describing a resilient SES. The seven qualities of the CRF are applied to 12 indicators that represent key functions that a city performs to increase its resilience. Examples of the 12 indicators are: empowered stakeholders, minimum human vulnerability, collective identity and mutual support, and continuity of critical services. As those examples show, the indicators would apply to some aspects of a city more than another.

The 12 indicators are evenly divided (i.e., three indicators each) into four broader categories entitled: Health and Wellbeing; Economy and Society; Urban Systems and Services; and Leadership and Strategy. There are a further 48 sub-indicators evenly divided among the 4 broader categories (i.e., 12 for each of the four categories) that operationalize the concepts. For example: Livelihoods and Employment is one of the three indicators within the Health and Wellbeing category. How do you measure the robustness and inclusiveness of livelihoods and employment? You would examine the sub-indicators of labor policy, skills and training, access to finance, and others to ensure all segments of the population are represented or have access to the benefits. This is a thorough operationalization of the concept of resilience for a city’s administration team to use in conducting an initial assessment, developing a plan to improve those areas found lacking, and then reassessing periodically to evaluate the effectiveness of their policies and programs. That is the process that the 100 city members of Rockefeller Foundation’s 100RC follow to increase their resilience.

This framework was developed specifically for the practitioner who has unlimited access to primary source data and a staff to gather, evaluate, and document it. In light of the sensitivity of some of the information, cities only share it conditionally to TCNs as survey input for aggregate data compilation or to organizations that require it for financing or to obtain other assistance. They do not provide it as open source information.

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In summary, the concept of resilience has its roots in ecology, but there is a concerted effort to bring it into the realm of social systems to facilitate analysis of SESs. There is, however, concern expressed in the literature that certain issues unique to the social setting, such as power, agency, politics, and influence, might make this concept a poor fit.\textsuperscript{33} To explore this fit, scholars are calling for further research using case study analysis to examine these social issues in the SES context. Case studies are good for testing, validating, refining, or refuting theories of which characteristics at what intensity level are necessary to have an adaptive cycle that perpetuates resilience. They are also good for creating new theories.

The CRF represents a commendable effort to operationalize resilience, build a base of data, and support cities in improving their adaptation to serious climate related hazards. When ample data are collected and the city resilience index is available for widespread use it may prove effective in assisting cities in their quest to lower their risks of climate instability. However, such an index may, in fact, be a manifestation of the conservation phase of the adaptive cycle with the associated hazard of increased efficiency that causes a loss of flexibility.\textsuperscript{34} For example, if a city committee is tasked with evaluating their resilience to SLR and has access to an index that provides measures of performance of peer cities, there could be a tendency to follow suit. They may adopt policies that worked in other settings, they may self-report a more favorable status than would an objective assessor, and they may choose mean degrees of a characteristic rather than devoting the time to decide what is needed in their specific setting. Using an index may provide a false sense of security or may waste resources. That is the downside of quantification of these qualitative concepts.

This study refers to the ten characteristics of resilience in the context of the Panarchy framework to evaluate the decision processes for adopting adaptation policies. Next we move to a discussion of the independent variables.

Independent Variables

Of the multitude of environmental, political, economic, and social factors that affect a city’s decisions for adaptation there are six of interest to this study. As briefly discussed earlier, they are: the history and future risk of SLR-related hazards, federation structure, membership in a TCN, financial capacity, risk tolerance to the hazard, and the influence of special interest groups. The following section is an in-depth description and operationalization of the independent variables.

History and Future Risk of SLR-related Hazards

Global warming is causing the sea level to rise around the world. This translates directly into a hazard because “rising sea levels raise flood levels,” which increases exposure and vulnerability if protection is not in place.35 Hazard is defined by the United Nations International Strategy for Disaster Risk Reduction (UNISDR) as “a process, phenomenon, or human activity that may cause the loss of life, injury or other health impacts, property damage, social and economic disruption, or environmental degradation.”36 The UN definition includes latent conditions that may manifest in the future. A more nuanced understanding of SLR as a hazard includes a discussion of causation, variances in type, intensity, and frequency; compounding phenomenon; and the effects of historical experience and future risk. However, as the focus of this study is social rather than ocean science, a brief summary will suffice. In a recent and comprehensive study Hansen et al. (2016: 3793) concisely explains “sea level rises as a warming ocean expands, as water storage on continents change (e.g., in aquifers and behind dams), and as glaciers, small ice caps, and the Greenland and Antarctic ice sheets melt.” Ocean dynamics is an additional phenomenon that causes relative SLR, and the slowing Gulf Stream is an example that is explained more thoroughly in chapter seven in the Miami case study.

Historical data suggest there was virtually no long-term average change in the global mean sea level from the first through the 18th century when it was about 8 inches (200 mm) below the 2006 level.37 From 1820 through 2004 the global mean sea level rose

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and the annual rate of SLR accelerated. From 1870-2004 the aggregate rise was 7.7 inches (195 mm) and the average annual rate of increase was 0.057 inches (1.44 mm).\textsuperscript{38} Within this timeframe, however, the rate of SLR varied and both 1930-1960 and 1993-2004 had higher annual rates of SLR, 0.1 inch (2.5 mm) and 0.12 inch (3.0 mm), respectively, than the intervening period.\textsuperscript{39} The acceleration of SLR is correlated to the rising global temperature with a 20-year lag.

What this dynamic effect of global warming on sea level means for coastal cities is that they need an equally dynamic adaptation strategy to protect currently and future exposed infrastructure. A number of organizations and agencies are developing models to minimize uncertainty and give city planners tangible ranges of probabilities with which to work. The IPCC Fifth Assessment Report (AR5) from 2014 is the most recent and its projections—Representative Concentration Pathways (RCPs)—are available with options to fit the level of risk tolerance and nature of planning.

As a phenomenon, SLR manifests as a chronic stressor or an aggravation of an acute shock to coastal communities. Chronic stressors, such as drought, SLR, social inequality, unemployment, and increasing pressure on health care services are disturbances that can interact with each other and combine to have a significant negative effect on a city’s resilience. If ignored, the slow erosion of resilience can result in death by 1,000 cuts. Acute shocks, in contrast, are abrupt catastrophes that cause extreme damage and capture the media’s attention, thus making them more effective catalysts for change. Examples of acute shocks include floods, bushfires, pandemics, tsunami waves, avalanches, mudslides, and extremist acts.\textsuperscript{40}

In addition to mean global SLR, many coastal cities have the added complication of land subsidence that is a result of land compaction from underground water extraction, near-shore oil extraction, and high-density built infrastructure on settling sediment. Land subsidence can occur anywhere drilling occurs, but when that activity occurs near the coastline it combines with rising water levels and results in relative (local) SLR greater

\textsuperscript{38}Ibid., 2nd of 4. Measurements are from both satellite altimeter data (1993 onward) and in situ tidal gauges.
\textsuperscript{39}Ibid., 3rd of 4.
\textsuperscript{40}Resilient Melbourne, Melbourne’s Resilience Strategy, by 100RC (1 June 2016) 11. 
\url{http://www.100resilientcities.org/#/-Yz46NzE3NydpPTEocz5j/} (accessed 1 June 2016). Source of examples of chronic stressors and acute shocks.
than the mean SLR experienced in other locations. Thus, land subsidence is a compounding factor that increases the severity, frequency, and duration of flooding in low-lying areas.

Next we consider hazards on the temporal scale, as past experiences that compose a city’s hazard history and as potential future hazards. Hazard history, regardless of whether the experience was with recurrent flooding or a catastrophic storm or both, is assumed to raise the level of a city’s motivation for adaptation to the changing environment to mitigate socio-economic loss. Further, the type of hazard experience, chronic or acute, is a factor to examine for possible correlation with the type of adaptation measures adopted. Is there a pattern of incremental adaptation measures taken in response to chronic stressors? Are more drastic adaptation measures only associated with catastrophic events? If so, which political and economic conditions exist in a city battling sunny day flooding that behaves contrarily to this pattern and makes a substantial adaptation investment to protect against the future risk of severe storms? Data on past hazard experience are available from city records and open reporting.

Moving on from the past experience that a city has had with SLR-related hazards, we now address hazard as a latent condition that represents future exposure and risk. Both future exposure and risk are operationalized and measured using data from two relevant studies.

The first study was for a 2008 Organization for Economic Cooperation and Development (OECD) report that estimated the exposure of 136 port cities to coastal flooding and storm surge and then ranked them from most exposed to least. Exposure was calculated separately for people and assets based on factual data from 2005 and then projected to 2070 using a model and different socio-economic and climate change scenarios. Exposure to the one-in-100 year extreme event was used throughout the OECD study, which is the standard exposure metric.

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For case selection and analysis in this paper I use the exposure estimates based on actual data from 2005 (Current City - C), and the 2070 scenario that incorporates socio-economic development from a 2008 OECD analysis and climate change based on the 2007 IPCC report (Future city, All Changes - FAC). The C scenario is a decade in the past and any influence on the case cities’ level of adaptation should now be apparent. The FAC scenario is fifty years in the future, which is appropriate to use for the urban planning cycle. The OECD report explains this timeframe saying current policy decisions regarding land use and hazard protection projects will affect exposure and risk levels in the 2070s.

The people and asset exposure estimates are useful in looking for correlation between type and extent of exposure and type of adaptation policy. For example, an appropriate adaptation policy for a city with a high level of exposure of assets to flooding can be expected to include protective projects to shield, waterproof, and float infrastructure to reduce its vulnerability. If the FAC estimate is significantly high, then an effective adaptation strategy would include inland retreat, relocation of informal settlements away from floodplains, and land use policies to reduce urban density and to increase the buffering capacity of the coastal ecosystem. The retreat strategy recognizes the limitations of physical infrastructure protection and reduces vulnerability by reducing exposure. Adaptation measures protect against exposure and reduce the risk of loss, which is what the next study addresses.

The second study (Hallegatte et al. 2013) uses the exposure data for both people and assets from the 2008 OECD report and builds on that to take into consideration the effectiveness of infrastructure-based adaptation measures and calculate the residual risk. The authors assess the economic average annual losses (AAL) using city-level flood risk assessments and a database of urban coastal protection for each of the 136 port cities based on 2005 data and projections to 2050.

43 Nicholls et al., "Ranking Port Cities...,” 13.
44 Ibid.
By doing this, the information is reframed from a rather abstract concept of potential future hazard to a tangible *annual* economic cost.\(^{46}\) This is because exposure metrics with a 1:100 year probability of event are subject to discounting, like other future events. Even though the estimates of numbers of exposed people and estimates of the dollar value of exposed assets quantify the potential, the worse case scenarios they represent seem like Black Swan events.\(^{47}\) That is, although these are high impact losses, they seem relatively safe because the 1:100 year *probability* seems low. However, the AAL is an economic cost for this year, next year, and every year in the future needed to cover the losses for when the Black Swan event occurs. Note the emphasis is on *when*, rather than *if*, it occurs. It is money that should be banked for the inevitable recovery and rebuilding after the storm. The AAL is the standard metric used for disaster risk management planning.\(^{48}\) It is consistent with a business or insurance model in which risks are viewed as costs, costs and benefits are weighed in decision making, and the data are used by a city’s Emergency Planning and Preparedness Director to develop appropriate adaptation policies to manage risk.

The message that the 2013 study delivers is that by viewing the economic losses in aggregate it is clear that business as usual is not an option. In 2005 the global economic losses from flooding totaled $6 billion, but by 2050 that cost will top $1 trillion in a worst-case modeled scenario factoring in socio-economic change, climate change, and land subsidence while maintaining current flood protection standards.\(^{49}\) For clarification, current standards of protection, which aim to maintain the present probability of flooding, require improving current flood protection in an environment of SLR. This requires raising the height of protective levees, for example, otherwise rising sea levels will overtop current levees more often, which would result in a higher probability of flooding.\(^{50}\) However,

\(^{46}\) Ibid., 806. To calculate the economic value of the loss of life the authors translated exposed population into exposed assets using recent work by the World Bank that estimates produced capital per inhabitant.

\(^{47}\) Talib, *Antifragile*, 6. “Black Swans are large-scale unpredictable and irregular events of massive consequence.”

\(^{48}\) Hallegatte et al., "Future Flood Losses..." 802.

\(^{49}\) Ibid.

\(^{50}\) Nicholls et al., "Ranking Port Cities..." 12. Footnote number 6 cites Muir Wood and Bateman, 2005. Definitions of the types of protective physical infrastructure failures as 1) *overtopping*: refers to seawater flowing over the defences without degrading the defence so as the flood levels diminish after the event, the
maintaining the current standard of protection does not maintain the current level of risk because of socio-economic and environmental change. For example, the AAL in Jakarta increases from $73 million in 2005 to $1.75 billion in 2050 if the Indonesian capital maintains the current level of flood protection. This is due to the projected growth in Jakarta’s population and economy as well as worsening SLR and land subsidence.\textsuperscript{51} For Jakarta, and all other cities that face SLR hazards, maintaining present levels of risk in the context of socio-economic growth requires adaptation policies that reduce flood probability over time.\textsuperscript{52}

The data from these two studies provide metrics of exposure and risk that operationalize the variable “hazard” tangibly and with granularity. Cities have access to this same information. Whether they adopt an adaptation policy proportional to the risk, however, depends on both available economic resources and non-financial factors.

\textbf{C40 Cities’ Membership}

A primary focus of this study is to understand the role that a TCN plays in a city’s adaptation decisions. At which points along the adaptive cycle does affiliation influence choices? There are more than 60 transnational climate governance initiatives and more than a dozen of these are public networks.\textsuperscript{53} C40 Cities is considered the preeminent TCN because of its membership of global and innovative cities; its partnerships with international institutions; its power as a global change agent; and its results, which comprise the climate actions of its member cities. Member \textit{global cities}—defined by Sassen as critical command and control nodes for information, finance, and other services in the networked global economy—can wield the influence of countries in many regards.\textsuperscript{54}

The benefits, opportunities, and access that affiliation with this TCN affords make it attractive to potential members. For example, if a city has experienced a heat, flood, or storm disaster and faces a future risk of more and has decided to take action they will look

\textsuperscript{51} Hallegatte et al., “Future Flood Losses…,” 802-03. Data from tables 1 and 2.
\textsuperscript{52} Hallegatte et al., “Future Flood Losses…,” 803.
to C40 Cities as a network of subject matter experts to assist in their learning process. In this regard C40 Cities is an intervening variable between hazards and resilience. To shape membership, C40 Cities requires cities to meet certain criteria. Beyond size and influence, a city must exhibit the commitment to take climate action to mitigate the causes of global warming and adapt to the environment of climate instability for the wellbeing of their city.

This variable also bundles other city characteristics, which are antecedent variables, such as a propensity to network, global city-ness, problem acknowledgement, and the political will to allocate resources for climate action. Since these factors would be difficult to discern from available data, the TCN membership screening process serves as a useful mechanism.

This is how it works. C40 Cities seeks cities that are key nodes in the highly networked global economy, meaning their influence is based on a “space of flows” more than territorial space. These world cities function extraterritorially, in many respects, to their benefit and that of their host nation-state. Their success is correlated to their propensity to network, their level of globalization is the driving factor behind their participation in a TCN, and active networkers enhance a TCN’s success. C40 Cities screens applicant cities based on three basic criteria—size, influence, and commitment. First, the core of the network comprises megacities, defined as cities with a population of at least 3 million, or a metropolitan area population of 10 million or more, either now or projected by 2025. Second, smaller cities with populations under 3 million are eligible to be Innovative Cities, which are recognized leaders in their field of environmental sustainability. Rotterdam and Venice are both innovative city members of C40 Cities. Third, whether categorized as a megacity or an innovator, each city that applies for membership must participate in the network as an “observer city” for one year. This year serves as a probation or trial period, depending on one’s perspective, which gives the TCN and the observer city an opportunity to see if membership would be a good fit.

55 M. S. Doel and P. J. Hubbard, “Marketing World Cities in a Global Space of Flows: Collaboration or Competition?” Globalization and World Cities (GaWC) Research Bulletin 64, 2001. The term ‘global city-ness’ is used to describe a characteristic of cities that are not defined by the geography they occupy but rather by their participation in a ‘global space of flows’ – transportation, communications, finance, politics, information, energy etc. Authors refer to Castells 1996 and 2000 publications.
Being a good fit requires the observer city to display the last two characteristics—problem acknowledgement and the political will to allocate resources. There is a distinction between problem recognition and problem acknowledgement in that the latter implies the mayor has the political autonomy, or support from state and national politicians, to publically acknowledge the risk that a hazard poses to the city. There are cities that recognize the increasing risk of not adapting to their changing environment yet are politically unable to publically acknowledge it because of the influence of powerful economic special interest groups with a vested interest in the status quo. An example is the relationship between politicians, special interest groups, and the environment in the state of Florida. There is mounting scientific evidence that Miami and most of the entire state are at a high risk of damage because of SLR. In a counterintuitive reaction to this risk assessment, Governor Rick Scott issued an edict in 2015 that prohibited state officials from discussing SLR because of its direct linkage with climate change. From Scott’s perspective this environmental problem, which could manifest as a social and economic problem, was, in fact, a political problem with negative financial ramifications. To appease his fossil-fuel-industry political campaign donors, he tried to de-link social behavior from global warming through terminology. Rather than using the climate scientists’ term “SLR”, Florida state officials were to say “recurrent flooding,” which implies a less threatening, long-term environmental phenomenon that was more palatable politically. This example illustrates that the problem with the solutions to climate change are social and economic, which makes them political, which makes them “super wicked” problems.

An unwillingness or inability to acknowledge the risks of global warming would be incompatible with membership in C40 Cities. Problem acknowledgement and the political will to allocate resources to climate action are complementary characteristics. Mayoral political will implies city leadership has prioritized funding climate action over other

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59 C40 Cities “Climate Action in Megacities” Volume 2.0, figure 7.1 Key Results, February 2014, 120. Report finds that 98% of city members report that the current and/or anticipated effects of climate change present significant risks to their city.
programs and has stakeholder support to do so. It does not assume financial capacity; that is a separate factor.

Operationalizing these factors is done in two stages. The propensity to network, global city-ness, problem acknowledgment, and the political will to allocate economic resources to climate action are bundled under C40 Cities’ membership. As such, this single factor is a control for a number of background conditions about the political economy of the city. Those factors are measured and evaluated by C40 Cities through the membership screening process. Membership is a binary YES or NO and the list of city members is found at the TCN’s website C40.org. There were 83 city members of C40 Cities as of April 2015, when case selection was done for this study.60

**Type of Government and Mayoral Authority**

A city’s political subordination to its host nation is a factual reality of the hierarchical political structure of our world order. However, the extent to which a city is reliant on, and thus controlled by, its higher levels of government varies considerably. Since this study’s analysis is at the city level, and the objective is to identify the factors and their influences on a city’s adaptation policies, a relevant issue is governance structure as it affects the mayor’s positional authority.61 Is the structure of government such that the mayor has the authority to make decisions? If so, we have the best opportunity to observe local cause and local effect. Cities are two levels removed from federal governance, consequently, the type of government at both the national and state levels will be considered.62

Federal republics and parliamentary democracies are the most decentralized forms of government. Both have institutionalized the division of power between branches and levels and are accountable to citizen voters. How the government was formed—either by separate self-governing states that gave specified powers to a central government while keeping control over local matters, or by a strong federal government that delegated

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61 Mayor is used as a descriptor of leadership in the city government, while knowing that the administration comprises myriad individuals working in committees to achieve their objectives. The term “Mayor” may not apply to cities around the world, but this term will be used to indicate that leadership in this study.
62 State denotes the intermediate level of government between cities and the federal level, and national denotes the federal level, which follows the U.S. government structure.
specified powers to states—is inconsequential. The Resilience and SES literature argue that the decentralization of authority inherent in these forms of government is more conducive to effective management of resources than the centrally controlled power of authoritarian governments. This study provides an opportunity to test that theory by comparing cities with decentralized and centralized authority.

At the next level down there is the political relationship between the state and city governments, which is strongly influenced by the division of power. If the state maintains strict control of authority, such as in United States (U.S.) Dillon Rule states, then city government powers are restricted to only those specifically conferred on them by the state General Assembly. This centralization of power stymies local initiative, is inefficient, and is contrary to the characteristics of resilience. If the state delegates authority to its cities and localities, such as with U.S. Home Rule states, then local governments can undertake functions that are not specifically precluded. The decentralization of authority is considered more effective for managing resources in a SES, is more efficient overall for decision making, and inspires innovation.

The relevance of the relationships between the federal and city governments and the state and city governments manifests in mayoral authority, city autonomy, and a possible dynamic with C40 Cities network. A city with a higher level of autonomy or a city subordinate to a stronger state that supports city-TCN affiliation is more likely to have an unencumbered relationship with C40 Cities. Variations on these factors may produce a more contested city-state affiliation. This would manifest in the higher level of government constraining the information exchange, resource allocation, or collaborative assistance to the lower level government. The net effect would be limited realization of the advantages of network affiliation, on the negative side, or protection of a city from investing resources in a maladaptive solution, on the positive side.

The challenge lies in accessing data and operationalizing “mayoral authority.” C40 Cities—a network of mayors—took on this challenge and developed a typology to operationalize mayoral powers. The typology was used in complying date from fifty-seven

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of its member city mayors who participated in the 2014 baseline survey, which was reported in the "Climate Action in Megacities."\footnote{C40 Cities “Climate Action in Megacities” Volume 2.0, February 2014. See reference for more information on mayoral powers. A relevant example of their typology is the mayoral power over Adaptation and Water Management on page 122.}

The typology categorizes four types of mayoral power as own/operate, set/enforce policy, control budget, and set vision, and then measures the extent of positional authority as either strong power or partial power. There was not an option to report no power, which may have skewed results by forcing mayors to either chose to inflate their authority to partial power or chose not to report, which would weaken the results, in those asset/functions categories in which they had no authority. Mayors self-reported the type and extent of power they had over myriad assets/functions across seven sectors pre-defined by C40 Cities. The seven sectors are Transport, Energy Efficiency, Energy Supply, Waste Management, Finance and Economic Development, Sustainable Communities and Adaptation and Water Management. The last of these sectors is the most relevant to this study.

One of the assets/functions of a mayor within the Adaptation and Water Management sectors is land use planning. Examining the data in the 2014 report on land use planning shows that of the 48 mayors that replied to this survey question, 39 reported having strong power in the own/operate type of power and 9 had partial power. The strong power to partial power ratio was 38:10 for set/enforce policy, 31:14 over control budget, and 36:12 for set vision. The ratio across this land use planning function is fairly uniform although more mayors reported having strong power rather than partial power, with only three mayors choosing not to report on it. In fact, these two observations are the pattern throughout this Adaptation and Water Management sector in that a mayor’s authority is weakest over the purse strings and there is a trend of less reporting on budget control. Silence from the three mayors could be interpreted as meaning they don’t have any power over the budget. Had a no power option been offered on the survey there would not have been this uncertainty. Each type of power is useful, but controlling the budget is more useful.
How can C40 Cities’ survey data be applied to this study? Not very well for at least two reasons. First, the date are an aggregation of (self-)reporting on subjective opinions of relative measures of unquantifiable abilities. Constructing a benchmark of this aggregate data and measuring another city against it compounds the inaccuracy and could lead to false conclusions. Second, information on any one city’s mayor’s positional authority is not accessible to external researchers, further hampering a comparison against an aggregate measure. However, the manner in which power (i.e., Mayoral Authority) was operationalization by type, by sector and, specifically, within the Adaptation and Water Management sector, may assist in the inductive analyses of the case study. For example, if one of the case study cities does not change zoning in flood-prone residential areas it may be a result of the mayor not having control over the budget necessary to finance relocation away from the high-risk area. C40 Cities operationalization of mayoral authority provides granularity on a broad and rather vague concept.

**Financial Capacity**

It is reasonable to assume that a city’s financial capacity is a critical factor in determining its allocation of financial resources, such as its outlay for built protection. And for cities with less financial capacity, that is the case. They cannot afford elaborately engineered infrastructure solutions, which means they must take other measures to decrease the vulnerability of their populations and infrastructure from flood. Their other option is to obtain financial aid or funding from outside sources.

On the other hand, wealthy cities in developed countries have both more expensive infrastructure and a greater financial capacity to protect their valuable exposed assets to a higher protection level than cities in developing states. And they usually do. For example, London and Tokyo protect to the 1-in-1,000 year flood and Amsterdam protects to the 1-in-10,000 year flood.

However, the literature shows that comparably wealthy countries do not protect to comparable levels. Two studies conclude that there is not a direct positive correlation between financial capacity, as measured by GDP per capita, and economic resources

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67 Ibid., 33.
allocated to flood protection. For example, New York City (NYC), as a wealthy city in a developed country, only protected to the 1-in-100 year flood, which is a lower protection standard than Shanghai, which protects to the 1-in-1,000 year flood. The Nichols study attributes cultural characteristics, and political and historical issues with influencing adaptation protection levels.

This suggests that the lack of previous experience with a catastrophic storm influenced NYC stakeholders to invest money elsewhere, rather than in protection against the Black Swan event. The Hanson study identified the risk averse nature of populations and their governments as a contributing factor to adaptation variance, which suggests a cultural bias regarding risk. This suggests that NYC has a higher tolerance of risk than Shanghai, which is reflected in the protection levels of U.S. and Chinese port cities in general. However, in 2012, Hurricane Sandy proved to be the low probability, high impact event that shocked the social system and became a catalyst for change that overrode past tendencies of a bias toward risk affinity. The city is spending $20 billion in infrastructure protection to decrease its risk of flooding.

This study will operationalize financial capacity as internal economic resources, which will be measured in GDP and GDP per capita. It will also consider the city’s access to external funding sources to determine if the source of financing influences decisions regarding the mix of engineered and social measures in the adaptation strategy.

**Risk Tolerance to the Hazard**

Risk tolerance is a factor measured on a continuum with extreme aversion on one end and extreme affinity on the other. As is the case for measuring resiliency, tolerance is context specific. Who is risk averse? To what are they risk averse? And in the collective, who benefits from a policy that is risk affine? Does flood insurance skew decisions toward maladaptive land use policies?

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68 Hanson et al., "A Global Ranking of Port Cities..., 104, and Nicholls et al., “Ranking Port Cities..., 9.
69 Nicholls et al., “Ranking Port Cities..., 33-35. The US is in a High GDP class and China is in a Medium GDP class. NYC protection standard was measured as of 2008.
70 Nicholls et al., “Ranking Port Cities..., 9.
Risk tolerance is an intervening variable that requires some unpacking. Consider the issue of what is the actual risk. Different actors perceive risk differently based on myriad factors including trust, worldviews, political affiliation, vulnerability, heuristics, socioeconomic and demographic attributes, and environmental beliefs. The complex and dynamic interaction of these forces also changes over time and scale. For example, as the intensity and frequency of episodic local flooding increase, and the trust in climate scientists increases, the likely effect will be an aggregate perception of increased future risk at the city level. If citizens trust their city politicians and the local government planning processes, then this may result in greater support for allocating resources for adaptation. On the other hand, if there is a lack of trust in the city planners and a perception that increased taxes to support adaptation would be diverted, thus equating to taxpayers throwing good money after bad, then a perception of increased hazard risk will not result in greater support for adaptation.

As a bundled set of characteristics, risk tolerance is difficult to measure. For the purpose of this study I define a city with a high valuation of assets exposed to flooding, a high economic AAL, and high GDP per capita that protects at more than the 1-in-1,000 year flood as risk averse. Those cities with the same exposure, AAL, and financial capacity to support infrastructure-based adaptation that choose to protect at less than the 1-in-1,000 year flood will be considered risk affine. An example of the former is Rotterdam since the North Sea Storm of 1953 (1-in-10,000) and the latter is New Orleans before Hurricane Katrina in 2005 (1-in-100). Such cities warrant further examination to tease out what contributes to this characteristic.

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Special Interest Groups

City stakeholders (i.e., private, public, and commercial) support decisions that increase their individual gain, but, because of their residency, they also have an attachment to place and a stake in solutions that benefit the collective, both now and in the future. They want to optimize, rather than maximize, benefits in a sustainable manner for the city. Relative gain matters, but absolute gain is also important. The influence of city stakeholders is key to understanding the political and economic dynamics at work within the city, between the city and other cities in the TCN, and between the city and the TCN during the adaptation process.

Special interest groups, for this study, are distinguished from city stakeholders by not being full-time residents, by preferring relative gain to absolute, and by discounting the future. The influence of external special interest groups can interfere with the dynamics of the city, sometimes profoundly. An example of this latter group is the oil and gas industry in New Orleans that has caused widespread ecosystem destruction and significant land subsidence through their offshore drilling transport operations.74 In general, external special interest groups focus primarily on extracting ecological resources. Once the resources run out they will depart for greener pastures. A major storm that raises the cost of extraction beyond the economic break-even point could hasten their departure. In this study, observations of a special interest group’s behavior that displayed an unusually high level of risk tolerance for SLR-related hazards would confirm this expectation.

A special interest group with an environmental or cultural heritage focus, on the other hand, would be expected to display a high level of risk aversion and may provide resources to raise the level of protection to decrease hazard exposure. For example, Venice and its lagoons were added to the United Nations Educational, Scientific, and Cultural Organization (UNESCO) World Heritage list in 1987, and more recently added to the endangered list due to its worsening recurrent flooding. The effect of this attention is that

74 Mike Tidwell, Bayou Farewell: The Rich Life and Tragic Death of Louisiana’s Cajun Coast (New York: Pantheon Books, a division of Random House Inc., 2003). Tidwell writes a first hand account of the extensive environmental degradation done through decades of offshore oil drilling. The channeling to accommodate pipelines fragmented the sea grass beds and other ecosystems features that decimated the seafood industry. The oil extraction caused land subsidence, which exacerbates SLR. And the damage from oil spills is well documented.
cities with a lower estimated loss probability and higher wealth may have a cultural factor that tips the scales toward a greater level of protection than would be expected. Venice and its lagoons is an example of a city with cultural characteristics valued well beyond its exposed population and traditional infrastructure assets.

**Control Variables**

Coastal cities face unique weather-related hazards and act proactively or reactively to their changing environment based on myriad social, political, and economic factors. The large number of variables at work in this context complicates identification of causal relationships between these independent factors and resilience. Controlling for two of the variables at the onset should facilitate better detection of similarities and patterns between cases that were selected based on their antithetical adaptation strategies.

**Global Port City**

Ports and shipping networks are the two critical components of maritime transportation. Shipping networks encircle the world reflecting the trade partnerships and health of the world economy. Ports are the nodes of maritime transportation where seaborne cargo and passengers come ashore and connect with rail, surface, and air transport for onward conveyance to their final destinations. The volume of maritime trade between two ports is the density of the network.

The large cities that grow up around busy trading ports are critically important well beyond their local area, which is a characteristic they share with other global cities. However, unlike those extraterritorial “spaces of flow,” the maritime transportation flow is firmly grounded geographically. Any disruption at a local port, whether it is weather or labor related, causes economic disruptions throughout the shipping network. The backlog of queued ships in the harbor waiting to come pier side, the idle employees, the stacks of containers, and the parked fleet of trucks represent lost revenue that emanates outward in concentric circles like tsunami waves from an earthquake. The occasional labor strikes at the Port of Los Angeles-Long Beach illustrate the extent of economic damage a disruption in this flow causes across space and time.

Controlling for being a global port city means adding a dimension of difficulty to the problem. Global cities are functionally connected in the networked global economy. As
Sassen’s research explains, the global cities that specialize in financing are virtually detached from their location. Most of these service hubs have information and communications processing redundancies built into their systems to protect against interruption caused by an extreme weather event. This is not the case for a port city. It may have the same communications network redundancies, but its primary function is in the material world of transportation. Port cities do not have the option of relocating away from the water’s edge because they are place-centric, meaning they are embedded in their particular locations, which makes them vulnerable to SLR.75 There are 136 port cities with a population over one million and 13 of the 20 most populated cities in the world are ports.76 The proportion of C40 Cities’ members that are global port cities is similar—45 of the 83 members of C40 Cities are ports.77

**History and Future Risk of SLR-related Hazards**

It is reasonable to think that a history of chronic flooding or a catastrophic event would be an impetus for a city to adopt adaption policies. However, whether, when and what type of adaption climate action a city takes depends on multiple factors. To illustrate the range of causal hazards and their accompanying costs we can envision parallel continuums. On one continuum lie SLR-related nuisance flooding, recurrent severe flooding, seasonal typhoons, catastrophic hurricanes, and saltwater intrusion. Parallel to this is the continuum of effects that can be measured in loss of life and property as well as in mounting economic costs. Present costs include recovery, rebuilding, and lost productivity. Less tangible costs include human suffering and the loss of future opportunity as people and businesses settle in a city deemed less risky. The many stakeholders with their individual interests will evaluate the situation after each disturbance and weigh the costs and benefits of business as usual compared to a change in policy. The range of adaptation policy choices lies on another continuum that does not run parallel to the two already described.

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76 Nicholls et al, “Ranking Port Cities…,” 7.

Hazard history is controlled for in this study because cities without a history of SLR hazard events were not considered for inclusion. However, the type, intensity, and frequency of hazard event history are not controlled. Not all case study cities have experienced a catastrophic storm. Controlling for SLR-related hazard history across the cases provides a common background condition that tests the resilience and adaptive nature of the system. It cannot predict a response because of the complexity of the SES. However, this study strives to understand the correlation, and potential causal relationship, between hazard events and changes in adaptation climate action in these cases.

**Factors of Key Interest – Not Controlled**

C40 Cities’ membership, type of government and mayoral authority, financial capacity, risk tolerance, and special interest groups are key factors of interest. A few of these factors deserve a short note in the context of case selection. First, C40 Cities membership is not controlled for in this study because doing so would skew the range of adaptation strategies. As explained in the earlier discussion of this factor, membership in C40 Cities requires meeting certain eligibility requirements including displaying a commitment to take climate action for the wellbeing of their city. Thus, a city that chooses to take no action in the face of increasing hazards would not be eligible to join C40 Cities. Choosing only C40 Cities networked cities would eliminate the maladaptive strategy of denial, which is on the extreme low end of the resilience continuum, from inclusion in this comparison of four cities with antithetical adaptation strategies. Not wanting to miss the rich contrasts a “denial” case brings to the study, one case will be a global port city with a history and future risk of SLR-related hazards that is not a member of C40 Cities. However, the other three of the four cases are members of C40 Cities indicating that they share a propensity to network, global city-ness, problem acknowledgment, and the political will to allocate economic resources to climate action. With the small n study we can observe differences between these cities that have the same access to opportunities that C40 Cities has to offer.

Along the same line of logic, the type of governance and mayoral authority factors are not controlled to allow a richer contrast between cases. Authoritarian rule
characteristically restricts access to factual information and controls lower level political decision making, thus limiting the availability of research data and the number of mayors who would be authorized to join a TCN—unless membership serves the central state’s purposes. With those constraints in mind, only one case is a city from a authoritarian federal government that centralizes decision making, and the other three case cities are democratically governed. By design, democratic states are weaker than centralized states. Selecting three democratically governed cities is a conscious decision to study cities that, theoretically, have the greatest leeway in urban policy making for adaptation to climate change. That is because less state interference will simplify observation of local adaptation to local environmental changes, whereas a strong central government is more likely to force cities to adopt policies aligned with national policies. National policies are adopted within the constraints of domestic politics and in the context of international relations. The twenty-year impasse on reaching an international agreement on global warming was a strong motivator for cities to take the lead on climate action. Cities do not have the same domestic political issues as federal governments and, thus, are viewed as ideal test beds for climate action experimentation if the federal government is so inclined to scale up those practices, strategies, and policies that prove effective.

Financial capacity is not controlled but its effect on when the adaptation process begins, what is the mix of engineered and social measures, and to what extent external financing is pursued are of interest. Varying this factor provides better visibility to this relationship. *A priori* one would correlate higher GDP with a mix favoring engineered infrastructure protection projects. For cities receiving external funding, the source may also influence the mix. An example of this would be World Bank funding that biases toward engineered solutions.

Risk tolerance is a more difficult factor to evaluate at the city level and since all city case studies are from different nations, this study may not contribute much in that regard. The single paired city case, Miami and Miami Beach, however, may provide some evidence

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78 COP 21 in Paris in November 2015 is a milestone in international agreement on mitigation of climate change. However, its non-binding nature jeopardizes its effectiveness and it is too early to determine if the agreement serves as a change agent in national behavior. Although mitigation and adaptation are distinct measures, the literature suggests there is a tendency for robust strategies that include both, once climate action is embraced as a priority.
on whether cities within a nation can have a different level of risk tolerance. If that turns out to be the case it would weaken the hypothesis that risk aversion is a national cultural characteristic.

Lastly, it is not practical to control for special interest groups in conjunction with the other controls. However, the presence of a powerful group that appears to have a discernable influence on delaying or denying needed adaptation or influencing what adaptation measures are resourced are examined closely. A strong oil and gas industry, for example, may disrupt the expected adaptation process in the reorganization stage and increase the risk of flood damage to an exposed city.

**Adaptation Strategies**

**Overview of Climate Action**

A city is a geographic place where people live, work, and play—and in a coastal city, people do all of that near the water. The primary function of a global port city shapes its identity. When a city’s population and other assets are exposed to the hazards associated with SLR the city’s stakeholders are responsible for reducing its vulnerability and increasing its resilience by implementing mitigation and adaptation measures—climate action. This section of the Research Design chapter provides an overview of mitigation climate action, a more in-depth discussion of adaptation climate action, and develops a typology of adaptation options that will be used in the comparison of four global port cities that have implemented archetypical adaptation strategies.

**Mitigation**

Climate action is categorized as mitigation or adaptation, although certain actions both reduce a city’s vulnerability to hazards in the near term and reduce factors that cause future risk. In fact, the most effective strategies combine complementary mitigation solutions and adaptation measures. Mitigation reduces the causes of global warming by decreasing the carbon footprint of human activity and increasing the environmental sinks. Examples of mitigation action are reducing energy consumption by either using less of it, or becoming more energy efficient by shifting away from forms of energy that produce carbon
emissions—coal, oil, and natural gas—to renewable carbon-free energy sources like solar, wind, and water. Not all fossil fuels produce the same amount of carbon dioxide (CO₂) when burned for their energy content. For example, coal emits 214-229 lbs. of CO₂, oil emits 161-214 lbs. of CO₂, and natural gas emits 117 lbs. of CO₂ to produce a million Btu of energy. Using fossil fuels that have a lower CO₂-to-energy content, natural gas rather than coal for example, decreases GHG emissions and is considered a mitigation measure. However, renewable energy sources, such as solar, wind, and water, don’t produce any CO₂, thus as mitigation measures go, the renewables are a much more effective climate-action option than shifting among fossil fuels.

Shifting to renewables is often discussed as a slow, incremental process at best, and dismissed as impossible at worst, because of the seemingly insurmountable technological hurdles and perception of exorbitant costs. In fact, studies find that the most significant obstacle is likely socio-political. In his 2009 study, Sovacool compares electricity generation capacity by fuel type in the U.S. with other countries and finds America at the trailing edge of renewable energy use. Wind, solar, biomass, and geothermal produce just 3.1% of the electricity in the U.S., 10% in Morocco, 15% in Egypt, 17% in China, and 20% or better in Canada, New Zealand, and a number of European countries in 2008. He makes the argument that the deeply institutionalized fossil-fuel-based-electricity industry is the “dominant paradigm” in American society and that the impediments to change are interconnected—with some being invisible to the public. The stakeholders who benefit from maintaining this status quo are powerful, have been effective in resisting change, and strategically frame the transition to renewables as being dependent on technology. This

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79 U.S. Energy Information Administration http://www.eia.gov/energyexplained/?page=nonrenewable_home (accessed 4 October 2016). Natural gas, coal, and crude oil are all considered fossil fuels because they were formed from the buried remains of plants and animals that lived millions of years ago, which makes fossil fuels nonrenewable.

80 Ibid., https://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11 (accessed 4 October 2016). The ranges of CO₂ emissions refer to the various types of coal—anthracite, bituminous, lignite, and subbituminous; and oil—diesel fuel, heating oil, that have different levels of carbon content which are emitted when burned for the energy they produce. British thermal units (Btu) is the standard used when measuring energy output.


82 Sovacool, “Rejecting renewables,” 4509.
cannot be the full story, however, because in our globalized economy the technology being used in Europe, Asia, Africa, and the Middle East to generate electricity utilizing renewables is certainly available in the U.S. In some cases it originated in the U.S. For example, although solar panel technology originated in the U.S., the U.S. share of the global solar panel market fell from 30% in 2000 to 7% in 2016, while China’s share soared from just 2% to 60%, for political, not technological, reasons.83

The technical feasibility of a complete global energy transition—electric power, transportation, heating, cooling, etc.—to renewable power was evaluated in a 2011 two-part study. Their findings were that technology is not the problem and that a water, wind, and solar power-fueled energy system could replace the existing energy system by 2050.84 Further, under certain circumstances and with strong leadership to address policy issues, the second part of that study found that the economic cost of energy in a world powered by 100% renewables would be around the same as our fossil fuel dependent world.85

However, one of the primary motivators to a transition away from fossil fuel also creates a significant problem to that transition. Climate change creates conditions of weather instability making reliance on wind and sunshine as power sources less certain now than in the past. The unavailability of power in high demand cities becomes a condition of economic risk that tempers enthusiasm for a complete transformation. Thus, transitioning energy sources is challenging and will take the full innovative power of both energy consumers and energy producers to work the solution from both the demand and supply sides.

Reducing energy use, increasing energy efficiency, and transitioning from fossil fuels to renewable energy sources are demand-side energy conservation measures that focus on decreasing emissions of GHG. Removing the GHG emissions that pollute the atmosphere is another mitigation action. There are primarily two methods, carbon capture and storage (CCS), or “sequestration,” and natural carbon sinks.86 CCS is a relatively new technological

85 Ibid., 1179.
process that does exactly what its name implies. Up to 90% of CO₂ emissions are captured at the smoke stack, for example, before they enter the atmosphere, then they are compressed to liquid form, transported by pipeline or by ship, and injected for storage in underground geological rock formations. Storage is in deep underground saline formations and in depleted oil and gas fields. Using CCS with renewable biomass as an abatement technology actually removes carbon from the atmosphere.

The International Energy Agency (IEA) is a proponent of CCS as a mitigation measure during the fossil-fuel-to-renewable-energy transition, noting its potential to stabilize and reduce the level of annual GHG emissions. They project that CCS can contribute up to 14% of energy-related CO₂ reductions needed by 2050 to limit global warming to a 2 degrees Celsius rise, a collective goal stated in the 21st Conference of the Parties (COP 21) Paris Agreement. They acknowledge, however, that CCS is expensive and the adoption of this process has been disappointingly, albeit understandably, slow—“not on track” in 2010 and are engaged with policy makers at the national and global levels to rectify this situation. There are a number of reasons for CCS’s slow adoption. The process is costly, highly technical, and consumes about 10-40% more energy than an industrial plant without CCS, which increases the cost of electricity 20-50%. Furthermore, there are potentially deadly problems with leakage. The IEA may have an uphill battle invigorating enthusiasm and financial support for CCS when the best method to remove carbon from the atmosphere is essentially free and fully renewable.

Trees are carbon capture and storage experts. They remove CO₂ from the atmosphere, use it as an energy source for their growth, and can store as much as half of

87 The Carbon Capture & Storage Association [http://www.ccsassociation.org/what-is-ccs/] (accessed 4 October 2016) and Global CCS Institute [https://www.globalccsinstitute.com/content/what-ccs] Both sites contain further descriptions of the process, benefits, and challenges.
88 Ibid., Carbon Capture & Storage Association.
93 Ibid.
the dry weight of carbon in their wood. Unlike oceans that are natural heat sinks that delay the effects of global warming, trees are natural carbon sinks that reduce the cause of global warming, which makes trees part of the long-term solution. In a balanced SES, the environment is able to absorb the CO$_2$ produced by society; however, we are no longer in that equilibrium range because the amount of CO$_2$ produced is beyond the carrying capacity of our current supply of trees. Increasing the number of trees will boost the environment’s ability to act as a carbon sink. The New York Department of Environmental Conservation identifies forest management, forest preservation, afforestation, and putting an end to deforestation, as the most effective, least costly, and most natural way of pulling CO$_2$ out of the atmosphere. New York is not unique—wherever they are adopted, these mitigation strategies will be effective, in cities and rural areas alike worldwide.

The effects of mitigation action that reduce GHG will take years to realize for the same reason that it takes years to feel the effects of global warming from the increased amount of GHG in the atmosphere. This delay between cause and effect is called climate lag time. Scientists explain this phenomenon as a result of the “thermal inertia of the oceans,” which is due to their vast size and their dominant role as the Earth’s heat sinks. There is a range of climate lag estimates, from decades to millennia, based on myriad conditions and a number of models, but a 2011 study for NASA estimates that 40% of the response will be felt in five years and 60% in a century. The full 100% climate response to the increased levels of GHG emissions in the atmosphere could take a thousand years to manifest.

Climate lag has two implications for coastal cities. First, the climate instability that cities experience now was caused by GHG emissions generated 50 or more years ago, and
the climate effects of the level of GHGs in the atmosphere today will be felt in about 50 years. This means that the effectiveness of climate action taken today to mitigate the cause of global warming will be obscured by the warming effect that is in the time lag pipeline. That does not diminish the criticality of reducing emissions, but the immediate costs and future benefits make it more politically challenging to accomplish. The second implication is that adaptation measures must be tailored to reduce a city’s vulnerability to future, uncertain hazards during the climate lag period before mitigation efforts are felt. Global port cities that are at risk now will absolutely be at a greater risk in 50 years, even if GHG emissions leveled off or decreased tomorrow.

Mitigation of the cause of climate change was the primary focus of the TCNs that were formed by mayors around the world over the past 30 years, and C40 Cities is a prime example. These municipal leaders realized that, in aggregate, cities produced 75% of GHG emissions and that they were in an ideal position to affect a change. During the process of learning about the problem, identifying options, and choosing mitigation policies, the unanticipated economic benefits of mitigation climate action became apparent. Reducing energy consumption, increasing energy efficiency, transitioning to renewables, and removing pollutants from the air reduced costs and indirectly increased revenue. People are generally attracted to cities that are cleaner, greener, and cooler and mitigation facilitates these improvements. TCNs and member cities advertise these attributes and the tourists, residents, and businesses that migrate toward these cities generate revenue. Another economic benefit is realized when a city creates jobs in the new technology fields that support mitigation, and, further benefits accrue when a city exports its technology and expertise (knowledge source) to a fellow member city (knowledge seeker) via the TCN and generates revenue. C40 Cities has been a conduit of economic opportunity for both mitigation and adaptation climate action for its members. Specifically, per its 2015 Climate Action in Megacities 3.0 report, 66 members of C40 Cities self-reported taking 9,831 climate actions to reduce GHG emissions and adapt to climate change since 2011.100

Next we will take a look at what constitutes adaptation to SLR for coastal cities. This starts by looking at the range of theoretical possibilities for adaptation approaches and options that are proposed in the literature, which are then organized into a typology. The discussion continues by considering the economic, social, and political constraints that city decision makers face, which, in practice, influence their policy decisions. Examples of measures implemented in the four case cities—Venice, Rotterdam, Guangzhou, and Miami—are interspersed to contextualize the theoretical and serve as a prelude to the research chapters of the study.

Adaptation

Whereas mitigation reduces the causes of global warming, the goal of climate adaptation is to reduce a city’s vulnerability by either minimizing the risk of, or maximizing adaptive capacity toward, the hazardous effects of global warming.\(^1\) Adaptation climate action increases the resilience of a city’s citizens and infrastructure and can be taken in reaction to, and/or proactively in anticipation of, climate change-related shocks. These shocks manifest as storm and wind damage from acute extreme weather events and gradually worsening flooding, salinization, and erosion caused by chronic, incremental, and accelerating SLR.\(^2\) The IPCC’s finding in 1996 that “accelerating SLR is the most certain consequence of global warming” has proven to be both true and one of the biggest climate change challenges facing coastal cities.\(^3\)

Approaches

How a city approaches the challenge of reducing the socio-economic impacts of these acute and gradual SLR hazards can be broadly categorized as choosing change, reducing losses, and accepting losses.\(^4\) In their 2003 paper, Klein, Nicholls, and Thomalla define each as follows.\(^5\) Choosing change means recognizing the climate-related hazard and adjusting socio-economic factors to reduce risk by changing land use or moving exposed populations. Reducing losses focuses on reducing the occurrence or impact of the

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\(^1\) Klein, Nicholls, and Thomalla, “The Resilience of Coastal Megacities...,” 109.

\(^2\) Ibid., 107.


\(^5\) Ibid. The description of these approaches is from table 8.4 and the narrative on 107-108.
event by, for example, building resilient infrastructure (e.g., flood-proof designs) and protective barriers, and installing early warning systems. Accepting losses means bearing (while maximizing resource exploitation) or sharing (via insurance and disaster recovery) the loss, both of which are relatively short-term economic decisions at the expense of the environment, which disregards the city’s future viability.

This categorization of adaptation climate action approaches is based on the extent of change required for strategy adoption and program implementation. Figure 3.4 provides a simple visual depiction of the three approaches placed along a continuum of change that begins at inertia, ramps up to various levels of adjustment from maintaining the status quo (accepting losses) through increasingly robust measures for reducing losses, and tops out at sustainable adaptation that reflects choosing change.

Inertia and maintaining the status quo mean that a city does nothing or implements minimal protective measures to maintain the status quo despite facing a significant SLR hazard. The city chooses to accept losses. Financial capacity is the obvious factor one would assume positively correlates with adaptation approach decisions since many measures are costly to implement.

![Figure 3.4. Continuum of change for adaptation climate action.](image)

However, more often than not, cities with the financial capacity to fund other approaches choose minimal protective measures or inaction because of the strong influence of special interest groups with vested interests in the status quo that actively block attempts for real change. In these cases, the economic incentive offered by the special interest groups outweighs current and anticipated losses and the city takes the risky
approach of *accepting losses*. Insurance may reduce the cost of the risk that is incurred by a few by diffusing it among many, or the actual risk may be masked by subsidized premiums that distort the market and encourage risk-taking behavior. Examples of special interest groups with an interest in preserving the status quo include resource extractors (e.g., oil, gas, or water), real estate developers, and those in the tourism industry. Their preference for maintaining the status quo reflects a higher utility on short-term economic gain and a discounting of the future—sometimes heavily. This may lead to resource exhaustion and irreversible environmental degradation, but they anticipate reaping a profit before that occurs.

Adaptation climate actions that range from minor to major adjustments are those changes adopted that reduce a city’s vulnerability and raise its resilience to varying extents yet fall short of approaching a sustainable relationship with the environment during a period of climate instability. “Adjustments” covers a wide middle ground of city adaptation strategies that aim to reduce losses by implementing options such as soft and hard-engineered protection, retreat, and limited measures of accommodation. Since most of the literature refers to this wide middle range of *adjustments*—where the majority of coastal cities operate in reducing their risk to climate change—as *adaptation*, that is the terminology this study will use. True adaptation that recalibrates social behavior to the extent that it restores the Earth’s energy balance and produces a sustainable social-ecological relationship would require all cities to *choose change*. The matrix of adaptation approaches and options, table 3.1, shows the relationship between these aspects of a city’s adaptation strategy and the relative extent of change they represent.106

*Choosing change* is the approach that provides the best probability for longer-term success, but decision makers often face insurmountable economic and social obstacles that undermine the political will that is required to support such extensive change. At the other extreme, the approach of *accepting losses* becomes increasingly expensive and is eventually financially and physically impossible. As we will see in chapter 7, the City of Miami is a prime example of a city that currently supports the approach of *accepting losses*.

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Table. 3.1. Matrix of adaptation approaches and options

<table>
<thead>
<tr>
<th>Approaches</th>
<th>Options</th>
<th>Extent of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Protect</td>
<td>Retreat</td>
</tr>
<tr>
<td>Accepting Losses</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Reducing Losses</td>
<td>✔✓</td>
<td>✔✓</td>
</tr>
<tr>
<td>Choosing Change</td>
<td></td>
<td>✔</td>
</tr>
</tbody>
</table>

Key: ✔ = less ✔✓ = more

The middle option, reducing losses, is the pragmatic “Goldilocks” approach that cities with large populations and economic values gravitate toward. Why is that? Reducing losses acknowledges the hazard—and the concern that stakeholders have about the risk—and dedicates resources to reduce vulnerability and increase resilience, yet admits that it is not logistically, economically, or politically feasible to abandon and relocate. This approach can be combined or applied in sequence with measures from the other two approaches. For example, a city may have an adaptation strategy of reducing losses by strengthening protection of existing infrastructure, flood-proofing design requirements and restricting land use zoning for new development, and activating an early warning system and robust evacuation plan in the short to mid-term. The longer-term plan, choosing change, for implementation when protective measures fail and the risk becomes unacceptable, would include relocating the most vulnerable segments of the population and shifting inland those functions formerly performed at the waterfront, if possible.

**Typology of options**

There is a wide range of options available to cities seeking to reduce losses by reducing the socio-economic impact of hazards. They are broadly categorized in the literature based on their objectives as: protect, retreat, and accommodate. These three
options encompass both structural and non-structural resilience-building measures. For the purposes of categorization, *structural* is defined as a property relating to the physical makeup of plants or objects that would be common to coastal areas and port cities, such as buildings, roads, bridges, and wharfs. *Non-structural* refers to individual social behavior and the interactions and organization(s) of people in a city. The typology of adaptation strategy options, table 3.2, aids in distinguishing options found in the literature. Although the options are analytically distinct, in practice they overlap and are fluid when implemented by a city in the context of a dynamic and interdependent ecological and social environment, over the course of time.

**Table 3.2. Typology of options for adaptation strategies**

<table>
<thead>
<tr>
<th>Options</th>
<th>Category</th>
<th>Characteristics</th>
<th>Mechanism</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protect</td>
<td>Structural</td>
<td>Hard-engineered armoring</td>
<td>Public and/or private funds</td>
<td>Barriers, dikes, sea walls</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soft-engineered ecosystem restoration</td>
<td>Public and/or private funds</td>
<td>Natural buffers, dunes, marshes</td>
</tr>
<tr>
<td>Retreat</td>
<td>Non-structural</td>
<td>Behavior modification</td>
<td>Zoning, insurance, awareness</td>
<td>Public education of risks and options</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maintaining coastal ecosystems, rolling easements.</td>
<td>Statutes, property rights, assessments</td>
<td>Public access to intertidal zones</td>
</tr>
<tr>
<td>Accommodate</td>
<td>Structural</td>
<td>Elevation, flood proofing</td>
<td>Policies, insurance, compensation</td>
<td>Moveable or elevated buildings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New development is prohibited, setback, or redirected</td>
<td>Zoning, laws, assessments</td>
<td>Hazard zones left uninhabited</td>
</tr>
</tbody>
</table>

*Protect* is the first and broadest category of options. Protection of physical infrastructure from erosion and inundation can be either through hard engineering
defenses like dikes, sea walls, back-flow preventers, bulkheads, dams, and other barriers combined with pumping systems that keep the water out; or soft defenses built to replicate natural barriers with absorptive features found in marshes, mangroves, dunes, barrier islands, wetlands, beaches, and reservoirs. Cities that adopt a proactive adaptation strategy have the option of employing both hard and soft-engineered protective measures in a complementary fashion for layered defense. Cities that delay or reactively implement measures following a storm may have missed the window of opportunity for implementing soft measures and must then rely solely on hard-engineered projects. The hard-engineered flood protection that is built closer to urban infrastructure provides close-in defense.

Building or maintaining existing marshlands, mangroves, dunes, sand bars and barrier islands provides a natural buffer as an outer layer of protection that literally keeps the storm surge at bay. Rotterdam and Singapore are two examples of cities dredging to reclaim land from the sea to build their shorelines seaward and create buffering barrier islands as insurance against SLR.

However, even if the wetlands and beaches are maintained (restoration of eroded beaches, nourishment to maintain a restored beach), the accelerated rate of current and projected SLR in all probability will exceed the coping mechanisms of the ecosystems. The effectiveness of these natural protective systems is predominantly a function of the space allocated for their inland migration in response to the encroaching sea. Without room to migrate, the man-made natural barriers must be maintained and nourished in place at significant expense to extend their dwindling period of effectiveness. Once that battle is lost, the hard-engineered barriers are what remain between the city and the sea. In some circumstances cities are situated in a manner that precludes the use of soft-engineered measures as protection from flooding. Venice, a city surrounded by its lagoon,

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is such an example. Venetian infrastructure is built on stilts and the tidal waters of the Adriatic Sea have free and daily access.

While built defenses are increasingly relied upon as being the most appropriate form of adaptation for high value immovable assets, such as cities, there are pitfalls and consequences of hard-engineered protection. They further degrade the environment, interfere with ecosystem migration, exacerbate sand erosion, and create a moral hazard in that those residing landward persist with risky behavior relying on the armorings to keep them safe. When built protection fails, it fails catastrophically. The catastrophic failure of the levee system in New Orleans to protect the city from Hurricane Katrina is a prime example.

In addition to addressing the geophysical vulnerability of a city, a city can build its resilience by addressing problems associated with its urbanization. If the rate of urbanization exceeded a city’s urban planning, an expansion of its drainage and sewage infrastructure, solid waste management facilities and services, and transportation and utility provision infrastructure can both reduce the likelihood and impact of flooding. These engineered solutions to urban problems can be complemented with non-structural protective measures such as land use zoning, public awareness of hazards and risky behavioral, flood insurance, disaster planning, and business continuity planning. Furthermore, studies have found that social resilience-building programs that address other aspects of citizens’ lives that are negatively impacted by climate change, such as their livelihoods, physical and mental health, and social connectedness (i.e., access to social capital through networks) are critically important. These programs aim to build

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resilience to make a community better able to anticipate, prepare for, respond to, and recover from chronic and acute SLR hazards.\footnote{Ibid., 531.}

A problem related to flooding is saltwater inundation of surface and underground freshwater resources. Protection from inundation requires emplacing tidal gates at access points to surface reservoirs and reducing the sedimentary permeability of aquifers.\footnote{Deyle, Bailey, and Matheny, “Adaptive Response Planning...,” vi.} Digging new surface reservoirs on higher ground further inland before existing sources are ruined is a water conservation measure that provides supply redundancy in the short term and a phased plan for water security in the longer term. Educating consumers about methods to decrease water usage is an example of a non-structural measure to lessen demand, which lessens the impact of inundation from SLR. Some cities, such as Rotterdam and Guangzhou, are using technology in innovative methods to reduce urban flooding and inundation. One method, used by Rotterdam, creates recessed public spaces that double as reservoirs for diverted rainwater during storms. Another method, used by Guangzhou, replaces concrete surfaces with permeable, peat-like material that absorbs, rather than channels, rainwater to refresh and replenish depleted and brackish underground aquifers. Both methods proactively manage the more frequent and intense rainfall to reduce flooding and land subsidence that result from climate change and urbanization. Lastly, Singapore is an example of a city combining technology and education in an adaptation measure to optimize the usage of water, a scarce natural resource for the city-state, through its “Toilets to Taps” wastewater recycling program.\footnote{DW Made for minds, Global Ideas, Singapore’s 'toilet to tap' concept”, 25 June 2013 http://www.dw.com/en/singapores-toilet-to-tap-concept/a-16904636 (accessed 23 May 2017).}

Retreat is the second category of adaptation strategy options. These strategies are primarily non-structural and can be loosely characterized as either maintaining the coastal ecosystem, or abandoning a developed area deemed too hazardous for the purpose of reinstating a natural habitat. The caveat “primarily” is used because in some instances structures are removed, however, nothing is built and the structures are not modified so the retreat option is essentially non-structural. Both retreat options prioritize maintenance of the natural coastal ecosystem at the expense of built infrastructure. They can be implemented proactively or reactively after either gradually increasing SLR creates an
unacceptable flood hazard or an abrupt event; in the latter case it would be part of disaster recovery.

The first option is a managed retreat of incremental change driven by the extent of SLR as assessed by surveyors, projected by climatologists, and regulated by law. It is a proactive measure to reduce losses on "high-hazard, coastal properties with long histories of flooding or structural failures". As with the soft-engineered protect option of adaptation, the city decreases the exposure of built infrastructure by relying on the coastal ecosystem to act as a buffer for storms and inundation. Unlike with the protect option in which the city recreates and renourishes a natural buffer seaward of development, in the retreat option the city provides unobstructed land for the beach, dunes, and wetlands to migrate landward as the sea advances, thus keeping them alive. Human activity must yield to the naturally migrating shoreline that has the legal right-of-way. This retreat technique is referred to in the literature as “planned retreat behind natural defenses,” and “rolling easement” strategies. The rolling easement concept is based on retaining public access to intertidal zones, as a priority over private property rights, on land affected by SLR, a concept enacted in U.S. state law to varying extents and enforced to a lesser extent. Mechanisms include “state statutes that permit the acquisition of public access easements through eminent domain, voluntary sales, or donations of conservation easements,” prohibition of hard-engineered protection or building in hazard zones, and the interpretation of common law principles that protect public beach access as the

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119 Abel et al., “Sea level rise, coastal development and planned retreat,” 280.
121 Abel et al., “Sea level rise, coastal development and planned retreat,” 280.
125 Ibid., author cites Texas law.
shoreline migrates landward onto private property. These types of retreat strategies are best suited for less-developed areas with the potential to sustain coastal ecosystems.

Implementation (enforcement) and cost are vexing issues. To illustrate, consider the costs and political viability of prohibiting beachfront homeowners from building protective seawalls on their property, which would impede public access, as their beach erodes and their abode becomes uninsurable, unaffordable, and eventually uninhabitable. In this scenario, a statute or common law principle existed prior to construction and the cost is borne by the individual homeowners. If those mechanisms were not in place it is more likely that the local government would pay the homeowners a (fair) market value for their properties before removing the homes, restoring the natural habitat, and returning public access to the land. The government would always bear the costs if roads, utilities, or other public facilities and infrastructure required relocation or demolition, removal, and replacement. Therefore, successful implementation of a managed retreat strategy depends on the identification of suitable properties, effective advance planning, and adequate acquisition funds in the government’s coffers.

The second retreat option, abandonment, implies that the land is no longer suitable for habitation or protection and the adjacent land is not considered safe for retreat. Two examples illustrate when a city would choose this strategy, the first is gradual SLR and the second is post-disaster. In the near future, Miami’s conditions of SLR, land subsidence, a porous substrate, and unchecked dense urban development will make it uninsurable due to its very high risk of flooding and inundation and the rising costs of recovery. Unfortunately, the entire southeast region of Florida is in the same dire straits that will require portions of the region to be abandoned in the future as the land returns to its former habitat as a seabed. The second example of abandonment follows a catastrophic storm that demolishes and inundates infrastructure beyond feasible recovery. Portions of post-hurricane Florida, Louisiana, Indonesia, and the Philippines are examples of areas not considered safe for rehabilitation, which were subsequently not fully repopulated.

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126 Ibid., author cites a court case supporting this in Galveston, TX.
Accommodation is the third category of strategy options, and it is the primary manner in which a city implements an approach of choosing change for adaptation to SLR. In choosing accommodation, decision makers recognize the nature of the dynamic and dangerous coastal environment, they deem it unsuitable for business as usual, and they resolve to institutionalize mechanisms that pave the way for society to accommodate the environment. There are structural and non-structural accommodation options, and a strategy that includes a range of mechanisms is more effective in strengthening a city’s resilience.

Structural accommodation for SLR consists of elevating and waterproofing infrastructure and buildings to stringent standards that reduce the risk of flood and storm damage. Applying these requirements to new construction is easier and less costly than applying them to existing infrastructure, but it can be done for both. New construction has the advantage of incorporating innovative climate proofing designs and technologies in architecture that are being developed and tried by other cities. Rotterdam is an example. The Dutch port city has devised innovative methods for accommodating SLR by incorporating its shipbuilding expertise into the construction of climate proof, floating buildings, such as their Floating Pavilion.129 New transportation infrastructure, such as bridges and roads, can be built higher based on SLR projections. Underground infrastructure (e.g., sanitary and storm sewers) can be water proofed with their openings fitted with seals that prevent backflow to guard against inundation, although in some cases the existing underground facilities may require replacement.130

Existing buildings can either be moved to a new location on higher ground at a greater distance from the shore or resituated on a raised foundation or stilts in the same place.131 The goal is to increases the horizontal and/or vertical setback distance of the building from the shore. The other option is after-market climate proofing that may make more sense than relocating buildings. Elevation and flood proofing incur costs, but these will be partially offset by continued insurability with reduced premiums that reflect the reduced risk.

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131 Abel et al., “Sea level rise, coastal development and planned retreat,” 280.
Non-structural accommodation is one of the most proactive options and serves as a preemptive move to avoid incremental retreat or abandonment. New development is either prohibited in hazard zones, and redirected to an area assessed as safer, or construction is allowed on the condition that a “setback” distance from the advancing sea is maintained.\footnote{Deyle, Bailey, and Matheny, “Adaptive Response Planning...,” 17-18.} Setback distances for land use policy are determined in the same manner for retreat via rolling easements. For example, Florida has a general setback distance of 30 times the average annual erosion rate of its sand shoreline, although, with the accelerating SLR that Southern Florida is experiencing, the setback distance frequently changes and the metric is obsolete.\footnote{Ibid., 18.}

Adaptation that accommodates SLR can be expensive, difficult to implement because of resistance from homeowners and taxpayers, and politically unsupportable because of the long lead-time requirement for planning. Although proactive measures are less costly in the long run than disaster recovery, some cities require a catastrophic weather event to be that change agent that motivates stakeholders to choose change. That was the case with Rotterdam and the North Sea flood of 1953, and probably many other coastal cities.

Land use policy is a critical mechanism for implementing both retreat and accommodation strategies and merits a brief discussion here. Decisions regarding land use policy attract significant interest from stakeholders with different objectives because they recognize the importance of laws, statutes, acts, and policies in a society governed by the rule of law.\footnote{Abel et al., “Sea level rise, coastal development and planned retreat,” 280.} As explained in the Abel et al. 2011 study, businesses lobby for economic growth, real estate developers lobby for building permission on the most desirable—marketable—land, conservationists lobby to protect ecosystems, and whichever expends the most resources, in the most effective manner, wins. In theory, politicians decide on policies that are in the best interest of their constituents while proclaiming a stated goal of the common good. In practice, the unspoken goal of reelection can be the most influential factor.

Legislating and enforcing changes to land use policy proactively in conjunction with implementation of other accommodation measures would constitute a strong adaptation
strategy. To be effective in the long term it must be complemented by mitigation climate action that makes a city carbon neutral. Scaling this to a regional and global level is the next step, one that is facilitated in theory by TCNs genuinely focused on the goal of reversing climate change, over the interests of short term economic interests. To reference an insightful author, long-sighted adaptation flies in the face of capitalism, which makes it economically unfeasible and politically impossible until those affected have had enough, and act collectively to become the societal change agent that reestablishes an ongoing cycle of adaptation that builds resilience in the SES.\textsuperscript{135}

Lastly, nothing is static. All factors that influence city decision makers are in a state of flux and those changes interact with others creating conditions that support shifting between the options and approaches depicted in table 3.2. New social behavior and environmental conditions emerge and others cease to be relevant in the complex environment of a city SES. An example of an environmental change agent is a natural disaster after which a city rebuilds infrastructure and modifies land use policies to higher protection standards to lessen exposure to the next storm and implements measures to protect against the gradual increasing threat of SLR. A new mayor, or a new funding source, are examples of social factors that could become change agents.

In summary, there is a wide range of mitigation and adaptation climate action options that city decision makers may choose from to reduce the cause and effects of global warming. Mitigation is key to the long-term solution, but since the environment is already in a state of climate instability, coastal cities cannot rely on mitigation alone. Therefore, they must incorporate complementary adaptation measures in a comprehensive strategy that decreases the vulnerability and increases the resilience of their population and infrastructure against the current and future risk of SLR-enhanced flooding and inundation. An effective strategy will assess the geophysical and urban conditions, and address the social, economic, and political factors that combine with environmental factors to perpetuate the unsustainable relationship.

\textsuperscript{135} Naomi Klein, "This Change Everything: Capitalism vs. the Climate," Simon & Schuster: New York, 2014.
Case Selection

The last step of the research design is selecting four port cities at risk of SLR-related hazards that have antithetical adaptation strategies—selecting cases based on the dependent variable. This entails a qualitative review of published resilience plans, adaptation strategies, and other available reporting and literature to find cities with widely divergent adaptation strategies to support the goal of providing a rich contrast for the case comparisons. As explained in the first section of this chapter, there is not an established objective index of resilience or, consequently, a ranking of cities based on their resilience. Nor are cities transparent about their self-evaluated level of resilience for understandable reasons. Climate action, especially for cities that belong to C40 Cities, is easier to access.

The pool of port cities considered was drawn primarily from two sources. First, the 136 port cities ranked as being at high risk of climate extremes and second, the members of C40 Cities. In April 2015 there were 83 affiliated cities in the TCN and 45 of them were port cities. Various sources were investigated to determine whether a city had experienced one or more significant catastrophic SLR-related event(s) or chronic and worsening flooding or both. That established their history of hazard type as being acute and catastrophic or chronic. The severity of a city’s hazard was based on calculations of their average annual losses (AAL) in 2005 and 2050 directly attributed to SLR.

From this narrower pool of at-risk port cities, then, the goal was to find cities that represent the different adaptation approaches and options as categorized in the typology developed in the last section. City adaptation strategies were a good source for that information. Lastly, finding a city that did nothing to adapt to a dangerous and dynamic situation required going outside of C40 Cities’ membership roster, since TCN members were not willing to accept losses as their adaptation approach.

The choice of cities was a subjective decision based on a review of the literature and open reporting. The four cities selected—Venice, Rotterdam, Guangzhou, and Miami—represent antithetical adaptation strategies. The strategies run the gamut from retreat to

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136 Nicholls et al., “Ranking Port Cities...,” and Hanson et al., “A Global Ranking of Port Cities...,” for the 136 port cities’ ranking. There were 83 Affiliated Cities per the C40 Cities website http://www.c40.org/cities as of April 2015.
137 Hallegatte et al., “Future Flood Losses...”; AAL is the standard metric in disaster risk management planning.
138 Reference table 3.1, “Matrix of Adaptation Approaches and Options” and table 3.2, “Typology of Options” of this study.
climate proofing to innovation to denial, and represent a wide range of resilience. How these adaptation strategies evolved will answer the study’s puzzling question—“Why have these four cities adopted antithetical government policies despite facing the same environmental threat from rising sea levels?”

Each case has a short introduction, followed by a description of the historical, geophysical, social, economic, and political factors that created the city’s current situation. This method establishes the SLR hazard first, and then analyzes the factors that influenced decision makers to adopt their adaptation strategy, which both reflects and affects the city’s resilience.

The following four chapters (i.e., chapters four through seven) present these city case studies starting with a short introduction that is followed by a description of the historical origins of the port city that weaves in the geographic and environmental characteristics that both attracted and posed challenges to early settlers. This account also establishes the nature of the SLR hazard and then moves into an analysis of the social, economic, and political factors that influenced decision makers to adopt their adaptation strategy, which both reflects and affects the city’s resilience. Special attention is paid to the relationship between the social and ecological components of the SES, evaluating whether it was in balance and resilient, and assessing subsequent changes in that relationship and any causal factors.

Chapter four is devoted to Venice and its lagoon and the behavioral adaptation policies that served the Venetians well until their decision-making process was disrupted by the storm of 1966 and a flood of external special interest groups that destabilized its socio-political system. Chapter five explores how the Dutch mastered water management through engineering solutions over a millennium during which they both reclaimed land from the sea to build Holland and institutionalized a balanced and sustainable relationship with the tumultuous North Sea and a destabilized climate. Shifting away from smaller democratic European port cities and pivoting to Asia provides an opportunity to examine a megacity in communist China. Chapter six presents Guangzhou and its innovative adaptation strategy of spongification that addresses the flow and absorption of water to reduce flooding. Chapter seven differs from the other case studies because it is a paired comparison of Miami—a port city in complete denial—and Miami Beach with its half a
billion dollar hard-engineered solution to tidal flooding. The neighboring American cities present a contrast to each other in the different strategies chosen by the two mayors in similar situations, as well as offering a contrast to the preceding three cases.

In sum, each city is examined separately, however, the second and subsequent cities (i.e., Rotterdam, Guangzhou, and Miami) will include comparisons of preceding cities. These cases are described and then analyzed to identify the social, economic, and political factors that influenced the city's decision makers in their perception of the problems they faced because of SLR and the strategies they pursued. Comparisons are made between the four cities as we move through each chapter with the goal of gleaning insight that will help explain how economic and political factors influenced decisions about adaptation that jeopardized or enhanced a city's protection of its primary function and identity. The variety of strategies from accepting losses to choosing change makes for a robust comparison.
CHAPTER 4

VENICE AND ITS LAGOON

Venetians are Retreating

Venice is a model of retreat based on its long history—over a millennium—of gradually adjusting social behavior to its gradually increasing flood hazard. The regularity of the occurrence of nuisance tidal and storm surge flooding has forced locals to make frequent minor behavioral adjustments to reduce losses, which has increased societal resilience. These frequent, scaled down adjustments to smaller disruptions kept Venetians more flexible and created a culture of tolerating flooding and this tolerance is now deeply ingrained into the broader fabric of their culture. The strength of this cultural bias toward toleration prevailed with the locals despite an abrupt catastrophic storm that would have been a catalyst for strategic change for other cities. What the storm did change, however, was the mix of actors in the decision-making process, which changed economic and political conditions and influenced a maladaptive shift in the city’s adaptation strategy. Because of this conviction for tolerating flooding by retreating upstairs or donning galoshes, Venice is an archetypical adaptation case study for retreat.

Description

Mainlanders who fled their homes to escape pillaging Visigoth marauders around 1,600 years ago were the initial inhabitants of the islands in the northern Adriatic. The shifting sand made the lagoons an unchartable labyrinth that proved inaccessible to the intruders, making the islands a refuge to those mainlanders fleeing the barbarians. In fact, this dynamic nature of the lagoons served to protect the Venetians by giving them a hometown advantage in security, during a time of captor-takes-all, land-grabbing instability.

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1 John Keahey, *Venice against the Sea: a City Besieged* (New York: St. Martin’s Press, 2002). Keahey provides a full historical account of the rise and glory, defeat, and challenges of Venice and her lagoon. It is a primary source for the following synopsis.
Over the next thousand years the residents of the lagoon islands turned their secure hideout in the Adriatic into a commerce-based city-state and a major maritime power. Their maritime skills, location, relative religious independence, and decision to focus on building trade rather than acquiring territory combined into a competitive advantage that was the foundation of their economic success. Venice became one of the busiest shipbuilding centers in the region and built a formidable navy able to project sea power great distances. As the Venetian Republic’s maritime trade grew, its economy grew, and its population grew. Venice’s power and population increased from the twelfth to the sixteenth century; at its peak 170,000 people lived in Venice and it was one of the largest cities in Europe.

To accomplish this, the Venetians built Venice in the middle of the lagoon (see figure 4.1). They stabilized their marshy environment by dredging, filling, covering, and redirecting canals to control the silt buildup caused by drainage from the Po and Piave Rivers. Had they not stopped the very process that had created the conditions for their initial security, the lagoon surrounding Venice and the islands would have silted over and become part of the Italian coastline. In fact, the city of Venice today is the result of expanding, merging, and connecting 118 small islands with 338 bridges. The original expansion of the islands began in the early ninth century and continued until the 1950s. The Venetians drove slender poles, made from local Adler trees, 10-15 feet through the mudflats into the more stable underlying clay-and-sand ground in densely concentrated patterns to support wooden and stone foundations for homes, shops, public buildings, and their ports. The building construction extended to the canal or river’s edge which then had its banks secured with bricks and cement. Over this eleven hundred year construction

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2 Keahey, *Venice against the Sea,* 49-50. The Venetians were more tolerant of other religious than most Christians of the time and their employment of Jews in banking was to their financial gain.
4 Keahey, *Venice against the Sea,* 57.
5 Adam Markham, Elena Ospova, Kathryn Lafrenz Samuels, and Astrid Caldas, *World Heritage and Tourism in a Changing Climate,* “Venice and its Lagoon, Italy” section. (United Nations Environment Programme (UNEP) Nairobi, Kenya; and UNESCO, Paris, France; and the Union of Concerned Scientists, Cambridge, MA, USA, 2016), 85.
7 Ibid., 65-66.
period the techniques remained essentially the same although machinery eased the manual labor requirements of pile driving and canal filling.

The Venetians also widened the inlets and dredged the lagoon to create deeper channels to accommodate shipping, which disrupted the ecosystem and endangered those living ashore. This construction essentially froze in time a landscape upon which they then added extraordinary architecture reminiscent of the Middle Ages, thus creating a timeless urban masterpiece on the water.\(^8\) The city suited the Venetians' purpose effectively for almost a millennium and has now become an iconic cultural treasure.

The environment can never be completely controlled, however, and the built infrastructure of Venice has been sinking gradually for as long as it has existed. The rate of sinking and the frequency and severity of flooding have increased over the course of time as a result of conflated manmade and natural causes. The combination of built infrastructure, which adds weight to the dense urban center; and groundwater extraction and offshore gas drilling that leave behind destabilizing voids; have caused the land to

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compress and subside. In fact, 4.7 inches (12 cm) of Venice’s 11.8 inches (30 cm) SLR is due to land subsidence, the remainder is climate driven.\textsuperscript{10} Making the rivers and canals rigid and dredging the lagoon increased the volume and speed of water movement, and blocked the natural process of refilling aquifers. Land subsidence and the thermal expansion of the waters of the Adriatic increase the region’s relative SLR, which brings each high tide and storm surge further inland. Often the tidal and storm waters surge up into the city via the former underground water catchment cisterns (see figure 4.2), which are dilapidated and open to the canals below, causing flooding without rain.\textsuperscript{11} When it does rain, the leveled, paved, bricked, stuccoed, and asphalted environment becomes a water chute that funnels rainwater into flash-flood conditions. In these ways the built environment is exacerbating the problem of SLR-related hazards.

\textbf{Figure 4.2.} Tidal waters rising and seeping through former underground water catchment cisterns in San Marco Square. (Image credit: Risner, 2 November 2016)

\textsuperscript{10} Markham et al., \textit{World Heritage and Tourism in a Changing Climate}, “Venice and its Lagoon, Italy” section, 86. Authors cite UNESCO 2011; Carbognin et al. 2010 as the data source.\textsuperscript{11} Rick Steves and Gene Openshaw, “Is Venice Sinking?” undated \url{https://www.ricksteves.com/watch-read-listen/read/articles/is-venice-sinking} (accessed 25 October 2016).
The city's intimate relationship with the sea has been primarily advantageous over the centuries. Some examples of the benefits of Venice's waterways and its access to the Adriatic include tourism, sanitation, and trade. Hordes of tourists flock to experience this unique city interlaced with waterways and to have a gondolier row them through the Grand Canal. The twice-daily high tides flush the city's open-air sewers (canals) and bring in fresh seawater from the Adriatic. Waterborne transport of goods enable Venice in its role as a global port and critical transportation hub for Italy and, more recently, the European Union (EU). The port currently employs 18,000 workers, and has dozens of passenger, cargo, and oil terminals that generate a combined annual revenue of €1.3 billion. In 2012 it was ranked as the tenth busiest cruise port in the world handling just under 2 million passengers, and generating €150 million in revenue a year. However, as the frequency and intensity of high tides, floods, and storm surge—compounded by SLR—increase, the cost of recovery and loss from water damage increase. For some, the cost of living in Venice is beginning to outweigh the benefits.

Over the long term, the gradual hazard from flooding has been met by a response of non-structural measures to reduce losses, such as water proofing, vertical retreat, and elevation. Residents don rubber boots to walk around town when the tide is in and many have converted the ground floor of their homes into a mooring or stowage space for small boats. Merchants followed suit by placing merchandise on pallets rather than the floors of their shops, keeping sand bags handy, and providing galoshes for customers who arrive

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16 Markham et al., *World Heritage and Tourism in a Changing Climate*, “Venice and its Lagoon, Italy” section, 85. Authors cite Comitato Cruise Venice as source of cruise ship passenger annual revenue.

unprepared. Over the centuries, foundations of new buildings were built higher than foundations of existing buildings to keep them out of reach of the rising sea. A more modern example of keeping infrastructure dry is the electric company's (i.e., ENEL) elevation of its system of transformers and ground-floor household and commercial plugs to higher positions on walls. They did just that following a major flood in 1953 that soaked the utilities' and caused power outages, however, the relocation was not high enough for the 1966 floodwaters.

An example of city led non-structural protection is the institutionalization of safety procedures to reduce the community's vulnerability to hazards. The city works in concert with the community to raise awareness and increase preparedness. Measures include sounding sirens as a warning for high tides; broadcasting information on the airwaves, on the internet, and via cell phones; emplacing elevated platforms in heavily-trafficked pedestrian areas (see figure 4.3); and rerouting waterborne public transport around low bridge clearances.

What had been an occasional flooding hazard—typically characterized as nuisance flooding—that was adequately mitigated with minimal protective measures or behavioral adjustments over centuries has now, however, become chronic flooding because of climate change manifesting as SLR. SLR is global, but Venice is experiencing relatively higher SLR. Based on tide gauge data from 1995-2003, the Adriatic showed a higher rate of SLR, ranging from 1.14–2.24 inches (2.9-5.7 cm), than both the Mediterranean SLR mean (0.85 inches or 2.17 cm) and the global mean (1.3 inches or 3.3 cm). This trend brings storm surges in higher and more often. An illustrative example is that the moorings that prevent

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18 Keahey, Venice against the Sea,” 193-194.
19 Ibid., 105.
gondolas from being swept out into the lagoon now also prevent them from washing ashore and into the piazza, a measure unnecessary in the past when the many steps up from the canal were not submerged.

The Italian term for high water is *acqua alta*, a term now also used by NASA and others when describing tidal water that rises high enough to inundate the streets and squares (piazzas) of Venice, which threatens historic architecture and alters the behavior of citizens. In the Venetian dialect, high water is called *aqua granda*, a linguistic difference that exemplifies the retained cultural distinctiveness of Italy's many provinces and regions despite national unification in 1861. In 1900 *acqua granda* inundated Venice ten times a year, but by 2014 the frequency of inundation was more than sixty times a year. The

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23 NASA Earth Observatory: *Where every day is Earth Day*, 2014.
24 While conducting field research 1-4 November 2016 in Venice, I observed a sign on the Teatro la Fenice commemorating a program for the 50th anniversary of “Aqua Granda,” A local explained that that was Venetian equivalent of the Italian “Acqua Alta.”
25 NASA Earth Observatory: *Where every day is Earth Day*, 2014.
increasing hazard is a more costly nuisance in daily life and is motivating the locals to seek other ways of dealing with their changing environment.

This is challenging because the geophysical characteristics of Venice limit its adaptation options. Sand cannot be brought in to create a seaward land buffer, as is being done in Singapore and some other coastal cities, because the lagoon would be lost. The city of Venice itself cannot be relocated inland or elsewhere because it is a collection of islands with fixed physical infrastructure on all sides surrounded by a lagoon that acts as a moat. For residents, moving inland means moving away from the ancient city and its lagoon to one of the four municipalities on the mainland: Mestre, Favaro Veneto, Chirignago or Marghera.26 Or, it means moving even further from home in Italy, or Europe, or elsewhere in the world. So, for those residents of Venice who don’t retreat upstairs, retreat must be out of the city; and many have left. The population of Venice dropped from 174,000 in 1951 to 60,000 in 2009,27 which makes the 2009 population lower than its population of 80,000 in the Middle Ages. SLR-enhanced-flooding is one of the many contributing factors to this exodus.

Concurrent with the outmigration of residents is the overwhelming increase in tourism. As full-time residency drops under 55,000 people, day-tripping tourist crowds now surpass 50,000, with peaks of over 200,000 visitors a day on special occasions and holidays.28 The consequence of these phenomena is that the entire character of the community has changed. UNESCO cites the devastating effects of Venice’s mass tourism as including “pollution, congestion, gentrification, and the crowding out of residents and non-
touristic activities,” and calls it unsustainable. Unsustainable in every sense: culturally, socially, economically, and physically. The other unsustainable practices cited by UNESCO are drilling for natural gas in the lagoon and dredging ever-deeper channels for commercial shipping. Both activities fragment, degrade, and destabilize the ecosystem and contribute to land subsidence, SLR, and flooding.

The Venetians’ long tradition of behavioral adjustments to the rising tides and gradual SLR became a path-dependent feedback that favored more of the same. The locals displayed strong opposition to building a barrier to protect against storms despite external pressure from UNESCO and other Europeans coastal cities, especially after the 1953 North Sea storm that hit Rotterdam and London so hard. The Venetians not only did not want a new barrier, they were even against investing the money to maintain an existing barrier. The existing barrier was a protective wall that had been built from 1744 to 1782—as the golden era of the Venetian Republic waned—but was left to decay and proved useless against current day levels of risk.

That local bias toward non-structural adaptation and against hard-engineered structural protection was based on a number of factors. Primarily, their adaptation strategy to retreat had been effective thus far against chronic flooding, as was mentioned earlier. The second factor was the exorbitant construction costs of a large engineered structure that they knew would cause an increase in their taxes—Italians have a well-known reputation for evading and avoiding taxes. Closely aligned with their aversion to paying taxes is a deep mistrust of government at all levels, which historically has been prone to corruption. Third, there is a perception that eventually Venetians will have to abandon the city as Venice surrenders to the sea because of its geophysical characteristics

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29 Ibid.
30 NASA Earth Observatory: Where every day is Earth Day, 2014.
31 Keahey, Venice against the Sea,” xiv.
32 Ibid., author reached these conclusions from interviews during research on Venice Against the Sea.
33 “Evasione Fiscale Italia – I numeri da conoscere” (translation:” Italian Fiscal Evasion – the numbers to know”), Forexinfo.it, 1 July 2015 https://www.forexinfo.it/Evasione-Fiscale-Italia-l-numeri-da-conoscere (accessed 21 October 2016). Article reports that Italy has the most major tax evaders in Europe, and that they did not pay over €180 billion in 2014 taxes.
in a future of climate instability.\textsuperscript{34} Thus, skeptics viewed the barrier as an expensive and temporary fix that might not prevent flooding. Environmentalists and the shipping industry were also against the barrier: environmentalists complained that the construction and barrier operation would further damage the lagoon ecosystem, and the shipping industry anticipated costly delays in ship traffic and port activity whenever the barriers were raised.

The locals’ resolve against a massive hard-engineered structural solution was weakened as a result of the disastrous 3-5 November 1966 storm. Heavy rains coincided with a high spring tide, strong winds, a sharp fall in barometric pressure, and a powerful storm surge from the Adriatic.\textsuperscript{35} This convergence of meteorological factors, on top of a sinking city, was categorized as a 1-in-800-year weather event.\textsuperscript{36} It brought floodwaters up to a record 6.3 feet (1.94 meters) in the lowest place in San Marco Square, water covered 80\% of the city, and it took fifteen hours to fully drain.\textsuperscript{37} All power and all communications were out for almost a week, but, fortunately, there were no injuries or fatalities.\textsuperscript{38} The lack of human casualties reflects the resilience of the Venetian population resulting from their behavioral adaptation to chronic flooding. The barrier islands, \textit{lidi}, bore the brunt of the storm’s wind gales of 60 m.p.h. winds and sea state 8 waves (18-25 feet or 5.5-7.6 meters), which swept over the little islands and swept away structures, cattle, machinery, boats, and small houses.\textsuperscript{39} The storm is blamed for the death of the majority of lagoon plant life and the end of lagoon agriculture.\textsuperscript{40} It was the worst disaster in Venice’s history and, as abrupt extreme weather events often do, it shook the locals’ faith in their non-structural adaptation strategy of retreat. It was time to reevaluate their vulnerability, risk tolerance, and options.

\textsuperscript{34} Keahey, \textit{Venice against the Sea},” 192-196. Throughout his interviews Keahey finds many Venetians who think it is inevitable that the city will sink into the lagoon and that a gate is only a temporary measure, albeit an expensive and disruptive one.
\textsuperscript{35} Ibid., xiv and 109.
\textsuperscript{36} Ibid., 158.
\textsuperscript{38} Keahey, \textit{Venice against the Sea},” 109-110.
\textsuperscript{39} Sea state is a simple scale that gives an approximate description of the surface conditions of a large body of water factoring in wind speed, wave height, and swell. The Beaufort Wind Force Scale categorizes dead calm wind as sea state zero and progresses through hurricane level wind at sea state twelve. \texttt{http://www.wrh.noaa.gov/pqr/info/beaufort.php} (accessed 18 October 2016).
\textsuperscript{40} Keahey, \textit{Venice against the Sea},” 110-111.
\textsuperscript{41} Windsor, “Inside Venice’s bid to hold back the tide,” \textit{The Guardian}, 16 June 2015. Paraphrase of a quote of Matteo Bisol, manager of a vineyard on one of the lagoon islands.
In the immediate aftermath of the storm that hit Florence and Venice, the overwhelmed Italian government appealed to UNESCO for help. UNESCO sent in disaster recovery teams whose reports documented the state of decay of the Venetian art, architecture, churches and museums, as well as the critically important supportive public spaces and canals. Art aficionados and historians were horrified. Thus a group of stakeholders beyond the city and state borders from the world of art, history, and culture, and UNESCO were infused with a sense of urgency in reducing Venice’s exposure to storms. They sent help, but with the financial donations came expectations that the locals and Italian government would take action to change the conditions that contributed to Venice’s vulnerability.

In 1987, as a continuation of their efforts to protect Venice, UNESCO officially recognized the “outstanding universal value” of Venice and its lagoon by designating it a World Heritage Site (WHS), thus boosting its iconic cultural status to the global level. Uniquely, this WHS designation pairs the socio-ecological components of Venice into an inseparable single identity. In their words, “the notion of identity therefore expresses the distinctive tangible and intangible features of a place which are evidenced by the relationship between a community and the territory within which it exists.” Specifically citing its architecture and art as linking the East with the West and Islam with Christianity, UNESCO claimed that Venice has influenced the world over the centuries, and that it must be preserved for future generations.

Over the course of time these stakeholders’ concerns have grown as the city’s vulnerability to flooding increased because of rising sea levels. Pointedly, the probability of a storm, with the same characteristics as the 1966 storm, hitting Venice is estimated to be 1

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42 Keahey, *Venice against the Sea,* 145-146.
44 ““Venice and its Lagoon,” [UNESCO website](http://whc.unesco.org/en/list/394) (accessed 17 October 2016). *Venice and its lagoon* is defined as the Ancient City of Venice, Burano and Murano islands, and many minor barrier islands including Lido and Pellestrina, that separate the lagoon from the Adriatic Sea.
in 200 years (as of 2002) as compared to its earlier categorization as a 1-in-800-year storm when it struck in 1966.\textsuperscript{47} These stakeholders wanted to decrease Venice’s exposure to strong storms and favored constructing an extensive protective barrier along the lines of Rotterdam’s Delta Works and London’s Thames Barrier. The idea of a protective barrier attracted other proponents. All wanted to protect Venice, but some were also motivated by financial and political gain. Hydro-engineering experts were drawn into the decision-making process to see what could be done within the constraints of the geophysical characteristics and in consideration of Venice’s function as a global port city. In 1988 they proposed a flood defense project that came to be called MÖdulo Sperimentale Elettromeccanicoor (pronounced MOSÈ), nicknamed ‘Moses’ in reference to the biblical Moses restraining the waters of the Red Sea.\textsuperscript{48} MOSE consists of a series of barriers, navigation locks, and breakwaters to keep high water and surges from reaching the city.\textsuperscript{49} The enormous barriers are hinged to, and rest on, concrete housing structures embedded in the sea floor when not in use so as not to impede either the flow of water, which keeps the lagoon healthy, or the flow of shipping, which keeps the economy afloat. When a high tide is inbound—43 inches (110 cm) or higher—the 78 gates that collectively form the barrier will be raised into position to seal off the three lagoon inlets—the Lido, Malamocco, and Chioggia—thus isolating the lagoon from the sea, to withstand sea levels up to three meters above normal.\textsuperscript{50} The entire positioning process can be completed within 30 minutes and the average high tide lasts 2.5 hours, meaning the disruption to shipping and other lagoon activity should only be four or five hours per precipitating event.\textsuperscript{51} After 15 years of study, discussion, and debate, the consensus—not unanimous—among stakeholders was that the project was technically sound in that MOSE should be

\textsuperscript{47} Keahey, "Venice against the Sea,” 158.

\textsuperscript{48} Windsor, “Inside Venice's bid to hold back the tide,” The Guardian, 16 June 2015.


able to protect Venice from catastrophic floods, albeit temporarily. The caveats explain that the barriers will keep *acqua granda* and storm surges out, but they cannot prevent sea levels from rising in the lagoon. Since the rising saltwater erodes the foundations of the city’s infrastructure at the water level, regardless of tides and storms, part of the threat remains.\(^\text{52}\) Another critique voiced by a prominent Venetian civil engineer who worked for UNESCO and argued that heavy rains contributed significantly to the 1966 floods. For this reason a barrier actually would have held that water *in*, thus increasing the flooding.\(^\text{53}\) A report from a UNESCO-organized workshop in November 2010 on SLR summed up the situation:\(^\text{54}\)

In conclusion, with the projections given in this report there should be no doubt that the sea level will eventually rise to a value that will not be sustainable for the lagoon and its historical city. The planned mobile barriers (MOSE) might be able to avoid flooding for the next few decades, but the sea will eventually rise to a level where even continuous closures will not be able to protect the city from flooding. The question is not if this will happen, but only when it will happen.

There remain two main points of contention about MOSE; the environment and the cost. First, scientific, environmental, and political objections have been raised about MOSE disrupting the natural water exchange between the lagoon and the Adriatic.\(^\text{55}\) As a rising sea level increases flooding, the barriers may be closed more often and for longer, which worsens pollution and makes the lagoon stagnant.\(^\text{56}\)

The second point, cost, is multi-faceted. Those funding the project, even if indirectly through taxes, cite its high direct and indirect costs. It is now estimated that MOSE will cost the Italian government €5.4 billion when complete.\(^\text{57}\) As such, it is the biggest public works project ever undertaken in Italy.\(^\text{58}\) The project has been plagued by delays and cost

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\(^\text{52}\) Markham et al., *World Heritage and Tourism in a Changing Climate*, “Venice and its Lagoon, Italy” section, 86.
\(^\text{53}\) Keahey, *Venice against the Sea,* 194-195. A prominent Venetian civil engineer, Paolo Pirazzoli, who worked for UNESCO, argued that the gates would not have prevented the 1966 floods.
\(^\text{54}\) G. Umglessor et al., “From Global to Regional,” Workshop Report 1, UNESCO, 18.
\(^\text{55}\) NASA Earth Observatory: *Where every day is Earth Day*.
\(^\text{57}\) Windsor, “Inside Venice’s bid to hold back the tide,” *The Guardian*, 16 June 2015. The cost estimate for MOSE as of 2015 is €5.4. This is $5.94 billion U.S. based on the 19 October 2016 exchange rate of €1:$1.10.
\(^\text{58}\) “Protecting Venice and its lagoon – A UNESCO World Heritage Centre,” *ABB in Australia: Power and productivity for a better world press release.*
overruns since its inception, when the original cost estimate was €1.3 billion less than it is now.\textsuperscript{59} Political corruption contributed to the scheduling and cost overruns as politicians availed themselves of the opportunity for monetary gain that the massive construction project provided.\textsuperscript{60} The then head of the construction consortium (i.e., Consorzio Venezia Nuova) responsible for MOSE masterminded the corruption that included bribery, kickbacks, extortion, and money laundering using a €25 million slush fund for politicians overseeing the public works project.\textsuperscript{61} Businessmen paid to cut through the notorious Italian bureaucracy. Politicians pocketed cash for personal gain and used the illegal payoffs to fund re-election campaigns, turning the financial gain into political benefit.

When the dust settled from the three-year Italian tax police-led investigation, it was clear that the Venetian’s deep mistrust of government officials was reinforced by MOSE. Newspaper accounts in June 2014 reported 35 arrests including the Mayor of Venice, a Minister of Parliament and former Cultural Minister, a retired police general, the President of Consorzio Venezia Nuova, and several businessmen.\textsuperscript{62} The controversy over the MOSE corruption scandal forced the resignation of Mayor Orsini on 13 June 2014 and is credited as being the primary motivation for the election of Mayor Brugnaro, whose primary campaign pledge concerned MOSE. He vowed to conduct a full investigation into all aspects of the MOSE project and clean up corruption.\textsuperscript{63} Following the arrests and local political shake-up, a material assessment uncovered a potentially fatal flaw in the construction. The steel used for the underwater hinges and pins that pivot the barrier sections that was

\begin{itemize}
\item Antonio Windsor, “Inside Venice's bid to hold back the tide,” The Guardian, 16 June 2015.
\item Windsor, “Inside Venice's bid to hold back the tide,” The Guardian, 16 June 2015.
\end{itemize}
originally tested, was not the same as the one used. The cheaper grade steel that was used is corrosive to marine chemistry, which jeopardizes the projected completion date of June 2018, raises the maintenance costs, and may cause structural failure. Numerous managerial checks and balances were put into place in the project management as well. The new procedures slow progress noticeably, to the point that construction has been halted, but it may facilitate eventual completion and keep the costs in check, unless the material problems doom the project. Ironically, MOSE as a project to protect Venice and its lagoon became an intervening variable that caused the election of a businessman who is a staunch supporter of shipping with a right-of-center political view—the first non-leftist mayor since 1960.

Other costs, beyond construction and political corruption, are the ongoing costs that will be borne by the shipping industry and port activities. Despite the relative efficiency of raising and resettling the barriers in 4-5 hours for a high tide, the direct costs of closures that interrupt shipping are estimated to be €548,323 to €1.29 million annually, depending on modeling hypotheses. In shipping, time is money and lost time is lost revenue.

A counter-point is that having MOSE in place serves as a preventive measure that avoids the higher costs of disaster recovery. Despite the port activity costs incurred during barrier closure, the authors of the economic assessment concluded that MOSE was a net gain for Venice. Another cost-benefit analysis that used estimated costs of maintenance and repairs incurred through annual flooding found that the barriers will more than pay for itself in fifty years.

However, a barrier to protect the city against storm flooding was just one of several issues identified by UNESCO as key contributors to the city’s demise. They include unbounded tourism, large cruise ships anchored in the lagoon, and increased ship traffic.

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65 Kirchgessner, “Venice mayoral election result.....”


67 Ibid., 348.

with its associated seabed dredging. Tourism, for example, is of key concern to UNESCO. Many of the almost thirty million visitors that come to Venice each year are tourists who sail into the lagoon on high-rise cruise ships and only stay a day or two. The high volume of pedestrian traffic and the short duration of their visits produce more wear and tear on infrastructure, more pollution, and less regard for the city and environment than do the city’s residents. This dynamic overwhelms the city’s maintenance and repair efforts, largely funded by its residential tax base. It also changes the character of the community.

However, tourism generates much revenue and reducing the current levels by implementing a sustainable tourism plan would reduce the flow of revenue, which is now necessary to finance MOSE, which makes change politically difficult.

UNESCO, the Italian government, and other stakeholders collaborated in developing a tool to manage Venice and its lagoon in a sustainable manner. Its strategy, policies, and processes were developed through a group effort led by the Venice office of UNESCO and agreed upon by those authorities responsible for its implementation. It was promulgated as the “The Management Plan 2012-2018.” Theoretically, this represents the collaborative polycentric governance hailed by Ostrom and collective action proponents as more effective than centralized decision making. However, in practice, it did not produce the desired results. Despite the WHS designation, the attention of new and external stakeholders, the influx of financial assistance, and the assistance with developing The Management Plan, action to preserve the city has not kept pace with the increasing severity of the environmental hazard, and the situation is worsening. Venice now tops the list of the most endangered heritage sites in Europe.

Furthermore, following its annual meeting in 2014, UNESCO tasked a team to investigate what progress the Italian authorities had made to date on the top remedial priorities of The Management Plan 2012-2018. Specifically addressing measures to correct

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71 Markham et al., World Heritage and Tourism in a Changing Climate, “Venice and its Lagoon, Italy” section, 85-86.
the conditions endangering *Venice and its lagoon*, the team’s October 2015 report stated that “no measures have been taken or that they are not sufficiently effective.”\textsuperscript{73} They concluded by recommending that the site be inscribed on the List of World Heritage in Danger.\textsuperscript{74} Because there are only three sites from “the West” on this list, the inclusion of Venice would be a source of shame to the Italian authorities and a likely trigger for close, unwelcome, monitoring of its actions in Venice by UNESCO.\textsuperscript{75} Intense lobbying by the Italian government bought them a year when UNESCO agreed to postpone their “name and shame” listing decision until its annual 2017 meeting.\textsuperscript{76}

This narrative describes the last two thousand years of Venice’s relationship with its lagoon and the rising water levels up to and including its situation today. It describes a tightly coupled SES and a web of interconnected actors working on their own behalf as well as that of alliances and the collective good. The increasingly dynamic environment is proving to be a formidable challenge to the stakeholders searching for effective adaptation solutions as the traditional retreat practice becomes less feasible.

**Analysis: MOSE is no Moses**

This case study presents an opportunity to look at key independent variables, the interaction of influential actors and factors, the decision-making process for selecting an adaptation strategy to SLR, as well as to evaluate whether that strategy is appropriate or maladaptive. I will address questions and test hypotheses that are at the core of this research while doing so. For example: How resilient is Venice to the hazard? Does the adaptation strategy facilitate Venice maintaining its identity and primary functionality in the context of climate change? Was the 1966 storm a catalyst for shifting strategies?

First, let’s analyze the interaction and effects of the six independent variables of this study—SLR-related hazards, risk tolerance to hazard, influence of special interest groups, financial capacity, federation structure, and TCN membership—on Venice’s decision-


\textsuperscript{74} Report of the Joint World Heritage Centre, 9.


\textsuperscript{76} Ibid.
making process for adopting adaptation policies. The city’s long history with chronic flooding was considered to be within a tolerable risk level by the locals who adopted an adaptation strategy of incremental non-structural retreat and protection. However, local and global behavior produced environmental changes that manifest by increasing the intensity and frequency of flooding, and, most notably, changed the nature of the hazard, which further raised the level of risk.

The 1966 storm broke the pattern of primarily gradually increasing chronic flooding to weather that now included abrupt and extreme storm flooding, although not yet life-threatening.\textsuperscript{77} It was a catastrophic event that weakened the strength of the argument of the predominately internal stakeholders’ (i.e., local Venetians, the shipping industry, and environmentalists) that favored continuation of the behavioral adaptation strategy and opposed construction of a barrier, albeit for different reasons. The locals and the shipping industry were primarily interested in protecting the functionality of the city as their home and as a global port. The environmentalists and locals had an overlapping interest in protecting the integrity of the lagoon as an ecosystem. However, the environmentalists and the shipping industry were the “strange bedfellows” in this three-way alliance because they were diametrically opposed on the issue of shipping channels—environmentalists wanted them filled and shippers wanted them deepened. Nonetheless, they formed a political alliance to oppose the barrier, despite their differences, as they knew that their voice as a collective would be stronger than their individual voices.\textsuperscript{78}

At the same time, the storm infused external special interest groups (i.e., art, history, and culture enthusiasts; UNESCO; and hydro-engineering firms) into the decision-making process. These new stakeholders lacked local expertise and agreed on the necessity for a barrier, but saw it as a means to different ends. The enthusiasts wanted to protect the art and its heritage—the identity of Venice, as they saw it.\textsuperscript{79} UNESCO shared their interest, but also wanted the city restored to a livable community for residents with enforced policies to

\textsuperscript{77} North, \textit{Institutions, Institutional Change and Economic Performance}, 89.
\textsuperscript{78} Keahey, \textit{Venice against the Sea},” 217-218. Author notes that the shipping industry in Venice is quite powerful because of the revenue the world-class port provides to the regional and national governments.
\textsuperscript{79} Ibid., 165. Author separates the effort to save Venice into two levels; protection of the city and lagoon itself as distinct from protecting the art and its heritage.
manage (decrease) tourism, which they considered a primary threat to the WHS's future. The hydro-engineering firms recognized the lucrative business opportunity that massive engineered infrastructure projects, such as MOSE, represent.

The three pro-barrier special interest groups had different sources of motivation. Each group individually engaged Italian politicians at the national, regional, or local levels and used their influence to sway their decision toward building MOSE. The philanthropic art community made financing the restoration of Venice's art all but contingent upon a barrier that would protect the city, and their investment. UNESCO stipulated construction of a barrier as a necessary protective measure to reduce the exposure and vulnerability of *Venice and the lagoon* as a WHS. The engineers wanted jobs and revenue, and were willing to share the wealth with local politicians, with whom they formed a close and mutually beneficial, albeit corrupt, political alliance.

The pro-barrier special interest groups became empowered stakeholders because the €5.4 billion price tag moved this project out of the local and regional authorities’ financial realm to the federal level with some international level attention. Funders earned a voice in the decision-making process. The new hazard, the perception of increased risk, and the lack of financial capacity resulted in the inclusion of special interest groups that moved the adaptation decision-making process out of the ‘small and fast’ level to the ‘intermediate size and speed’ decision-making level of the Panarchy model. By moving out of the local level, national political institutions were able to exert greater influence on both the timing and outcome of decisions.

Italy is a particularly rich case in this regard. Beyond the usual inefficiencies characteristic of a parliamentary republic, such as being deliberative and thus slow to reach the requisite consensus for decision making, the Italian Republic experienced uniquely high turnover in national leadership. There were twenty-five different Prime Ministers between the 1966 flood and the approval for MOSE in 2003. It would be unlikely that this high turnover did not contribute to the time delays, cost increases, and the overall weariness felt by those at the local level trying to retain their share of influence on their adaptation policies. The absence of uninterrupted national leadership diminished the

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cohesion and credibility of national influence, which raised the relative influence of both local and external international leadership on decision making. Further, the investigative commission (UNESCO 2015) specifically reported that the decentralized government structure of Italy had facilitated a lack of shared vision for Venice, a lack of intergovernmental coordination, and that the government has been unhelpful in forming a coherent response to the prioritized problems that require immediate attention. This could be a product of the discontinuous leadership or a characteristic of weak central governance over historically autonomous regions, provinces, and cities. Regardless of the cause, the effect is that Italy’s governmental confederation is an intervening variable that slowed decision making and stymied the efficient construction of MOSE.

In addition to expanding vertical influence in the decision making about Venice’s adaptation, there was also horizontal expansion. London and Rotterdam shared with Venice their experiences in building and operating the Thames Barrier and Delta Works, respectively. The transnational city collaboration before construction on MOSE actually started was informal networking, since it predated the establishment of TCNs, including C40 Cities. In fact, their informal networking is likely to be a contributing factor to the establishment of I-STORM (International Network for Storm Surge Barriers) which is now cited as the conduit for ongoing collaboration between the North Sea cities and Venice. Nonetheless, the pre-C40 Cities collaboration does support nor falsify this study’s first hypothesis that wealthy networked cities favor hard engineered structural barriers for their SLR adaptation strategies at the expense of behavioral modifications. Those earlier intercity relationships also influenced Venice’s participation as a relatively new, innovator city member of C40 Cities. As such, Venice acts as an information source exporting specialized knowledge and best business practices on adaptation measures to other port cities.

Addressing the question of whether the 1966 storm was a catalyst for shifting adaptation strategies, the factors discussed above are strong evidence to support an

82 I-STORM is a specialized TCN established in 2006 to facilitate the sharing of information, best practices, and to facilitate transactions between its four member cities—London, Rotterdam, Venice and St. Petersburg. https://www.i-storm.org/i-storm.html (accessed 24 October 2016).
affirmative response. However, rather than shift strategies from behavioral to hard-engineered structural measures, Venice has augmented its behavioral adaptation with defensive protection against acute weather events. Venice moved to the right within the *reducing losses* area along the continuum of change for adaptation climate action.

Testing the second hypothesis, which states that C40 City members’ horizontal networking will partially bypass any blockage at the national level, but may also preempt development of a more locally inclusive adaptation strategy from the bottom-up, with the Venice case is literally irrelevant because the decision for MOSE was made in 2003, two years before C40 Cities formed and well before Venice became a member in 2012. However, the case is unusual and presents an opportunity to test the hypothesis so let’s assume the pre-C40 Cities transnational networking between Rotterdam, London, and Venice represents the networking that has occurred since C40 Cities was formed. This hypothesis addresses the agency of a city as empowered by a TCN and the effect of a TCN’s agenda on its member cities. The case of Venice inverts the context assumed for Hypothesis number two. Venice was not struggling to implement adaptation measures against an uncooperative Italian government. To the contrary, Rome usurped Venice’s ability to retain decision-making authority because of the scale of MOSE and the influence of international actors. In this regard, Rotterdam and London were in cahoots with UNESCO and the pro-barrier special interest groups who were in opposition to local stakeholders who preferred the behavioral-measures-only adaptation strategy. Although this does not apply to C40 Cities because of the timing, it is not a stretch to understand that the influence of these cities independently or as part of the TCN could influence a decision made by cities or by national governments on their behalf. From the national or international perspective, Venice could be seen as an obstacle blocking its national government from a preferred adaptation strategy. The second part of the hypothesis refers to preempting development of a more locally inclusive strategy from the bottom-up, which the case of Venice falsifies. The threat of MOSE actually increased solidarity between the local stakeholders opposing its implementation, even though their resistance was not strong enough to win.

Hypothesis number three states that abrupt and catastrophic weather events are a necessary, although not sufficient, condition for adopting an adaptation strategy that requires either an allocation of significant financial resources or entails a significant change
to land use policy.\textsuperscript{84} This refers to the theory of discontinuous change, and the Venice case supports this theory, although with the caveat of time. The 1966 storm changed the nature and level of future hazard risks, increased the visibility of this risk, attracted external stakeholders and resources, and shifted decision making from the local to the national level with international influence. Venice significantly changed its millennia-long strategy of behavioral adaptation by adding the gigantic engineered barrier, albeit after 37 years of debate.

The 1966 storm was a catalyst for change in Venice’s adaptation strategy. The storm also had second and third order effects on the city. For example, the inclusion in its adaptation strategy of an engineered solution (i.e., MOSE) with its massive infusion of money was an external financial shock to the SES that caused a significant political change to the city. Rather than the daily tidal amount of money that flowed into the city and was filtered through the politician’s pockets, MOSE financing was an abrupt once-in-a-mayor’s-political-career storm surge of money. The level of corruption crossed the national government and citizen’s thresholds for tolerance and, rather than accommodate it, they opted for drastic change. They halted the project, fired the personnel, conducted a damage assessment, voted in a new mayor and political party, and are building many layers of protection against further corruption to increase their resilience against potential future hazards. If lessons have been learned regarding the potential for corruption that these extraordinary engineering projects include, then they should be incorporated into discussions that C40 Cities and other TCNs—with their bias for engineering solutions—have with other like-situated port cities.

Does the adaptation strategy facilitate Venice maintaining its identity and primary functionality in the context of climate change? UNESCO’s designation, the high volume of tourism, and common reference suggest a consensus that casts ‘Venice and its lagoon’ as an inseparably linked entity, thus an appropriate assumption would be that saving Venice must include saving the lagoon. The behavioral and anticipated engineered measures that now comprise the adaptation strategy decrease the risk level for both components. The deeply institutionalized process of behavioral accommodation is incrementally adjusted, as

\textsuperscript{84} See chapter three - Research Design, page 50. This refers to Douglass North’s theory of discontinuous change.
climate change affects *acqua alta*, thus minimizing the effect of daily gradual flooding so people can continue to live, work, and play in Venice. If the new barrier becomes operational, and if it is effective, it should decrease the vulnerability of the population and reduce the exposure of the physical infrastructure to the acute hazard of extreme storm surge flooding. On the other hand, unless the new mayor is able to salvage the project, MOSE may never become operational.

However, even if it works, MOSE is a temporary measure if the trends of climate change continue as predicted. A transformative adaptation strategy would entail separating Venice from its lagoon. Preservation of the art, architecture, livability, and land-based value of the city would be at the expense of the lagoon that would have to be filled. This would be a return to the environmental pattern of shifting sands, halted hundreds of years ago by the Venetians, that will eventually incorporate Venice into the mainland as a coastal city. It would be the end of the locals’ intimate relationship with water throughout their city; a relationship which many consider its heritage and identity. Building this sand/land buffer around Venice and retaining its viable functionality as a global port may be the next major engineering project, although it is unlikely the city’s political system could survive it.

Long-term sustainable adaptation options for Venice that have been discussed are variants of turning the lagoon into a lake. One version is building a walled lake and the other is “the Dutch solution” in which the lagoon would be separated from the Adriatic with a series of dykes and locks to allow a controlled exchange of water.85 These Dutch options would preserve the city’s historic setting to a greater degree than merging Venice with the mainland. In view of MOSE’s 50-100 year estimated service life, the stakeholders should begin discussing the options of either transforming the lagoon into a lake or sacrificing the lagoon to save the city. These alternatives to indecision and inaction are controversial in every respect—socially, culturally, politically, and economically—in addition to being massive and complex engineering projects that have requisite long lead-times for planning.

Is Venice’s adaptation strategy appropriate or maladaptive? Overall Venice’s behavioral accommodation and retreat are the appropriate fit for a chronic condition that gradually increases. The inclusion of MOSE as an adaptation measure is less appropriate

85 Keahey, *Venice against the Sea,* 210 reference to the walled lake and 268-269 reference the Dutch solution.
because of its high cost, planned obsolescence, uncertain effectiveness, late inclusion in the city’s strategy, and the institutionalized political context of Venice and Italy. In these respects, the barrier is maladaptive. This suggests that the hazard type (i.e., chronic or acute) is not the best factor upon which adaptation strategies should be based. The appropriate strategy must take into consideration its interaction with the social, political, and economic institutions of the city.

Lastly, there is the issue of resilience. How resilient is Venice to SLR-related hazards? Venetians have not suffered a casualty in a flood in hundreds of years; that is one metric of resilience. Their reliance on themselves and their community make them resilient to chronic flooding and the occasional storm. Decisions on adaptation policies have been at the local level and characterized by inclusive dialogue based on local knowledge. The frequency of flooding serves as a training program to hone their preparedness skills and to perform daily functions in a city others would abandon. Some locals have left, but this is more a result of economic factors. Tourism is creating a level of economic inequality and is pricing many Venetians out of both the housing market and their community making Venice more of a museum city than a livable city for locals.

This begs the question of how resilient Venice is to tourism, which is an equally challenging hazard because its volume correlates positively and directly with degradation of both the built and natural environments, upon which tourism is based. Yet tourism is now the lifeblood of the Venetian economy, making efforts to curb tourism politically unfeasible at the local level. So, although the city is not physically, socially, or environmentally resilient to the current type and level of tourism, at the same time it is not economically or politically resilient to a radical decrease in tourism revenue. The power of the attraction of short-term economic gain is greater for locals than the discounted future costs of the physical and cultural damage from excessive tourism. However, external national and international stakeholders are now part of the decision-making process regarding the sustainable level of tourism and new alliances are likely forming to debate the issue in light of UNESCO’s 2017 meeting.

Interestingly, Venice appears to be politically resilient to SLR-related solutions. Their democratic institutions and frequent turnover of elected officials enabled a rapid election—two days after the arrested mayor resigned—without an interruption of business
for those not directly involved with the MOSE project. Change is a normal function of democracy and the Italians’ exceptionally high rate of change make their political institutions more flexible than others.

The last point to consider is the effect that these actors and their actions had on the community’s resilience. First, although the influx of stakeholders infused more diversity into the decision-making process, it also diluted the level and influence of local expertise in that process. Venetians consider anyone not originally from and currently living in Venice to be an outsider who, regardless of their intentions, is unfamiliar with their situation and institutions and, thus, unqualified to decide on solutions to their problems. The Venetian’s maintain a staunch belief in the inherent security of their inseparable socio-ecological coupling with the lagoon, which means they can and will adapt their behavior to whatever the sea, and changing climate, bring. This guided them to reject the barrier. However, their voice was overpowering and there were unintended and, at least to outsiders, unanticipated consequences. If the locals maintain the cohesive community that served them well in the past, do not adopt a false sense of security based on the barrier, and continue to rely on themselves to live with flooding, then Venice should remain resilient. The resident to tourist composition of the city’s population will affect this.

In sum, what the case of Venice and its lagoon portrays is a cohesive social community defined by its relationship with its ecosystem, which has, over time, developed a strong path dependency of incremental behavioral adaptations to incremental changes in the tides of the Adriatic Sea. The ongoing process of adaptation has remained at the small and fast level of the Panarchy model of nested adaptive renewal cycles. Even the storm of 1966, because of its lack of loss of life, would have been within the realm of local resolution. However, the abrupt weather event captured international attention that brought in external special interest groups that place a high value on the museum city’s artwork and architecture. They were given access to Venice and its adaptation decision-making process by the financially strapped national government. This intrusion by external powers resulted in imposition of a new, engineered solution to what they perceived the hazard to be. That is, a hazard of storm surge, which does not address the chronic tidal flooding.

The case of Venice portrays clearly the battle between alliances formed by internal stakeholders and external special interest groups wielding various forms of power for their
individual, collective, short and long term goals. In the end, the locals’ perpetual distrust of their politicians and the corrupt political institutions was vindicated, although that did little to solve their bigger problem of accommodating an ever-encroaching sea. From an historical institutionalism perspective, Venice is a strong example of the tenacity of path dependency. Despite the power of UNESCO, Dutch hydrological engineers, and scientific projections of ever-rising seas, the Venetians continued to favor behavioral adaptation over engineered measures. The corruption of the corporate-political partnership at the city and national levels prevents effective collaboration between civil society, and the public and corporate sectors, making a continuation of their current strategy—the status quo—likely.
Rotterdam is the second global port city to be examined in this chapter. Rotterdam and Venice have a lot in common: both were built on, around, and over the water, both became economic powerhouses as a result of their coastal locations; and both are increasingly vulnerable to SLR. In fact, two meters of SLR puts both cities well underwater. Despite their commonalities, the Dutch and Venetians took antithetical approaches to adapting to their soggy environments. The Venetians built Venice incorporating the water of the lagoon into their city and their lives and have adopted a strategy of adapting to chronic flooding that centers on behavioral modification. In contrast, the Dutch removed water from the land and built and maintained a firm sea-land boundary through their strategy of flood proofing.

The Dutch expanded their country by reclaiming land from the North Sea through the construction of berms, dikes, dams, and water-pumping systems that drained and kept the water out. In doing so they lowered their land, essentially creating relative SLR and intensifying their hazard risk of flooding. Periodic floods prompted the Dutch to strengthen their defenses against the sea and this cycle of engineering projects and floods forged their adaptation strategy of structural accommodation. Engineering solutions that weather proof infrastructure against flooding developed into an institutionalized bias. Only in the past decade, with the new chronic hazards that climate change pose, have the Dutch shifted from weather proofing their infrastructure to climate proofing their society by including behavioral modification in their adaptation strategy. This represents shifting approaches from reducing losses to choosing change to accommodate their new ecological reality. Because of their expertise in engineering and water management, Rotterdam is the archetypical adaptation case study for climate proofing.

1 There is a visually powerful map that depicts flood zone at various levels of SLR [http://flood.firetree.net](http://flood.firetree.net) (accessed 30 November 2016).
The following examination of Rotterdam identifies historical, environmental, political, economic, and resiliency features of the city as well as the role of stakeholders and any TCN influence. The subsequent analysis of their decision making includes comparisons with Venice and concludes with an articulation of the Dutch climate proofing adaptation model.

**Description**

The story of the little Dutch boy who plugged a small hole in a leaking dike with his finger on his way to school is mythical, but portrays the self-sacrifice, collective action, and awareness of the hazard of flooding that are characteristic of Dutch society. Dutch society was, and continues to be, shaped by the geography of the land that the Dutch literally steal from the sea. As was the case with Venice and the Adriatic Sea, Rotterdam and the rest of the Netherlands (“neder lands” translates in English to “low lands”) were formed by warming temperatures and SLR after the last Ice Age, around 10,000 years ago, when melting ice flooded what was then a large lowland plain and created the North Sea. What became a small, flat country that is less than twice the size of the state of New Jersey (2015) is located at the mouths of three major European rivers—the Rhine, the Meuse, and the Schelde—and is riddled with estuaries, and bordered to the north and west by the powerful North Sea. These geophysical characteristics provided the perfect environment for experimentation on which early settlers honed their management of the sea-shore border.

A short note to explain *dike* and *levee* is useful here for clarification. Dike comes from the old English term *ditch*, the Middle Dutch term for *dam, mound or pool*, and in German it means *embankment*. Levee comes from the French term *terre levée* meaning

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4 The World Factbook, Central Intelligence Agency. https://www.cia.gov/library/publications/the-world-factbook/geos/nl.html (accessed 30 November 2016). The Dutch have been expanding the physical landmass of their country through reclamation to the extent that a size estimation must be date-stamped to be accurate.

5 *Water Management in the Netherlands*, Rijkswaterstaat, 12-17.
elevated earth. All terms refer to the ditches and their mounded embankments that separate land from water, which is a dynamic demarcation as water levels rise and levees and dikes are built ever higher. The two terms are commonly used interchangeably, as they will be here.

Water management began a long time ago in the Netherlands and dikes are an integral part of that history with the earliest evidence of dikes dating from the Iron Age (800 BC). The soggy moorland provided a rich bounty of natural resources such as fertile soil, fish, water, lumber, good river transport, and safe ports that attracted a progression of Germanic tribes—Nervian, Frisians, and Batavians—as well as Celts, Romans (55 BC-410 AD rule), Saxon, and Franks. These Dutch ancestors settled the land, fought for control of the resources, and built rudimentary berms. Archeological evidence depicts these initial berms as consisting of stacked peat sods covered in sand and clay to form gradient barriers that shaped and secured the shifting geography and kept the sea out. In this way, early settlers engineered ways to maximize access to resources while evading the reach of frequent North Sea storms and minimizing flooding from overflowing rivers.

Water management really took off during a time of more benign weather (circa 1000-1800) because climate stability is ideal for cultivating land to support a growing population. As the population increased, so did the demand for agricultural products and more arable land; demands that the Dutch as a society successfully met by reclaiming land from the water. The cycle of land reclamation and flood defense was described as “the battle of the Dutch against nature is in fact a battle against processes they themselves started earlier.” In their article on the history of Dutch floods, Tol and Langen explain the

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7 Eric-Jan Pleijster, Cees van der Veeken, and Peter Veenstra, Dutch Dikes, History section, LOst LAndscapes (LOLA) http://dutchdikes.net/history/ (accessed 18 November 2016).


9 Pleijster, van der Veeken, and Veenstra, Dutch Dikes.


long and close connection between their cultural, political, and economic institutions and the water—specifically the hazard of flooding. The Dutch aversion to the risk of flooding and determination to reduce their vulnerability is a common cultural bond that drew them together in collective action. It is the foundation of Dutch communitarianism.

About half of the Netherlands is situated at or below sea level on land that was annexed from the sea—polders. A polder is a tract of low land reclaimed from a body of water, such as the sea or a lake. The Dutch have perfected this annexation by using dikes to isolate the sea from a bay and then employing windmills to pump out the water. Once drained this former seabed or inland lake becomes dry land on which the Dutch build communities that are often below sea level, yet safely separated from the displaced body of water by a protective dike. As windmill technology improved the Dutch built larger and larger polders to combat flooding and expand the land available for agriculture.

An example is the Beemster Polder, which is the first large Dutch land reclamation project (1607-1612). The ambitious project required draining an inland sea, the lake of De Beemster, using 43 windmills to create a 28-square-mile (7,208 hectares) agrarian polder that lies 11.5 feet (3.5 meters) below sea level and on which the municipality of Beemster developed. The original windmill technology used to construct the Beemster Polder 400 years ago was not replaced with three steam pumping stations until the late 1800s, then later by diesel and finally fully-automated electrical power.

Beemster together with its canals and dike rings was inscribed to the UNESCO WHS list in 1999 noting its contribution as a “masterpiece of creative planning,” “profound and lasting impact on reclamation projects in Europe and beyond,” and “a major step forward in the interrelationship between humankind and water at a crucial period of social and economic expansion.” The second of those three criteria reflects the use of Beemster as a

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15 Ibid., in Brief synthesis section, and UNESCO WHS Beemster and de Schermer.
16 Ibid., in Integrity section.
17 Ibid., in Criterion section.
polder model that has been replicated over the centuries and throughout the country. As a result, an aerial view of the Dutch landscape is unique as a showcase of recurring patterns of municipalities at the hubs of outwardly radiating canals bisected by encircling rings.

The Beemster Polder is an example of a methodology that has been perfected over time and enhanced by technological advances. Figure 5.1 highlights the progression of land annexation in the Netherlands from the 18th century through the present. The history of how the Dutch arrived at and improved upon the Beemster model provides insight to both their engineering prowess and social institutions. The engineering and technical history provided by Oosthoek’s overview of Dutch water management from the 11th-20th century

![Figure 5.1. Land Reclamation on the North Sea Coast.](https://fluswikien.hfwu.de/index.php?title=File:Land-reclamation-on-the-north-sea-coast-map.jpg)

notes some distinct phases. The earliest phase consisted of building up levees, draining the water from the moorlands, and cultivating the land for farms around which communities grew up. This draining led to dehydration, settlement, and land subsidence that both brought the ground closer to the water table and caused relative SLR with the sea and rivers. The polders inadvertently became water catchment from four directions—the water table from below, rain from above, and lateral river overflow inland as well as storm surges from the sea. Strong winds blowing in from the north and northwest are funneled landward and force water up into a surge onto the coast of the Netherlands, not unlike the northern Adriatic Sea surges into Venice.

There was a period of strong surges from the North Sea accompanied by gradually increased flooding, reportedly in the 12th-14th centuries, that influenced a ramping up to the next phase of water management. This phase focused on strengthening flood protection by building a more intricate system of dikes parallel to rivers to widen the river basin, thus creating a floodplain to increase the river's capacity to accommodate heavier water flow when needed and to prevent flooding. This method was effective in the short term, but not the long term because the heavier flows included silt that accumulated in the riverbeds and both raised the riverbeds above the level of the floodplains and decreased the discharge capacity of the rivers leading to overflow. To correct this problem and decrease the risk of flooding the Dutch raised the height of the dikes. This was another short-term solution that proved ineffective in the long run. During the rainy season heavier water flows rushed through the rivers or canals next to the higher dikes and caused more frequent occurrences of breeching and flooding. During the cold season the narrowest parts of the canals froze into ice jams—especially during the Little Ice Age (circa 17th and 18th centuries)—that forced the level of water to rise and overflow the barrier, thus flooding the adjacent land.

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21 Ibid., 359-360.
23 Ibid.
24 Ibid., under “River flood management in the 19th century” section.
The intensification of water management was enabled by the economic rewards of land cultivation for agriculture and pastureland and was in reaction to flooding that included some catastrophic events. For example, one of the largest floods in recorded history is St. Lucia’s flood of 1287. It smashed through a series of dikes killing more than 50,000 people and reclaimed a large area of land near the North Sea inlet that became known as the Zuiderzee (South Sea).25 There were also severe floods in 1313 and 1315, major sea surges throughout the 15th, 16th, and 17th centuries, and two other disastrous storms in 1825 and 1916 that wreaked havoc, took thousands of lives, and reclaimed land to the sea.26

Each storm and flood was met with resolve to mitigate the risk of future flooding through the construction of mounds, transverse dikes, and overflow and lateral diversion channels. This latter system focused on diverting and managing water rather than resisting it and was characterized by setting aside and designating land for surge water storage capacity; it became the primary strategy for flood management in the 19th century.27 However, the advent of technological advancements, industrialization, and population growth influenced a shift away from this flexible approach to water management back toward a strategy of resistance later in the 19th century.28 Advancements in hydrology, construction technology, and the proliferation of steam engines enabled the building of higher and heavier dikes and locks to control water better.29 There was a transitory period of a dual-tracked strategy of both dynamic and resistance solutions to protect against flooding, but by 1900, as the use of arable land for spillways was viewed as economically inefficient and wasteful, the strategy fully shifted to one of rigid, engineered flood defense.30

To this point, the Dutch adaptation strategy for reducing losses progressed from being primarily reliant on the implementation of hard-engineered structural protection measures to a broader approach that included soft-engineered measures that replicated

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28 Ibid., under “River flood management in the 19th century” section.
29 Ibid.
30 Oosthoek, “Dutch river defences” under “The 1950s and beyond” section.
natural systems of managing water supply, but then reversed this decision. The dialectic nature of the Dutch adaptation process illustrates the waxing and waning of economic factors that favor short-term productivity goals over longer-term sustainability.

The Zuiderzee, that inlet of the North Sea created by the storm of 1287, was a force multiplier for all of the subsequent storms, including the deadly storm of 1916. And, although the Dutch had plans for a massive engineering solution, they had not embarked on it for decades due to its technical complexity, high cost, and a lack of political will. The 1916 storm was the first storm covered by mass media and the broadcast motivated civil society to financially and politically support the plan to repolder the Zuiderzee, thus pushing the North Sea out.\(^{31}\) The two-stage process consisted of constructing the 19.9 mile (32 km) long Afsluitdijk (Closing Dike) from 1927 to 1933, and draining the landward portion of the shallow Zuiderzee to create an entirely new twelfth province—Flevoland.\(^{32}\)

The Zuiderzee Act of 1918 marked the beginning of the Zuiderzee Works. The giant dam rose 25-feet (7.6 meters) above sea level and barred the North Sea’s access inland and eventually converted the saltwater Zuiderzee to the freshwater Ijsselmeer (Ijssel Lake).\(^{33}\) The dam required an investment of $710 million (in 2004 US dollars), was completed two years ahead of schedule, and has effectively protected the northern part of the Netherlands from storm surge and flooding.\(^{34}\) The Dutch use of the term “investment” rather than “cost” reflects their inclusion of indirect costs and benefits. In the case of the Afsluitsijk, agricultural and business gains from the newly created Flevoland recouped the cost of the Afsluitsijk.\(^{35}\) With the Afsluitdijk complete, the Dutch started the second stage of the project and by 1967 they had reclaimed 895 square miles (2,318 square kilometers) of land from


\(^{34}\) Ibid.

the sea and built four polders, despite setbacks during WWII. The Zuiderzee Works was the Netherlands’ largest hydraulic engineering project in the 20th century.36

The size and complexity of these engineering projects required and received considerable planning, financing, and cooperation; not surprising given that administrative cooperation between independent Dutch communities dates to the Middle Ages.37 The earliest institutionalized cooperation (circa 13th century) took the shape of local “water boards” comprising landowners working together to address issues of drainage and dike-building for communal safety and the continued economic viability of their agricultural livelihoods.38 The common goal of reducing flood risk led local water boards to collaborate horizontally and to reach up vertically to include nobility and the church as stakeholders in decision making, thus expanding cooperation from the local to the regional level.39

Collaboration on water defense was as fundamental as defense against invaders to Dutch citizens and was a key factor in advancing its political union. The first formal Dutch union dates to 1433.40 In the beginning of its Golden Era, which covered the 16th and 17th centuries, The Republic of the United Netherlands was established (officially in 1568) as a loose federal political structure that gained strength and credibility during the 80-war with Spain for independence.41 Defense was costly, but essential to survival so all citizens paid a share of wartime defense via taxes. Water defense was handled differently. Originally landowners were individually responsible for maintaining the portion of the dike(s) adjacent to their property and if they were found to be delinquent during inspection by the local water board representative, the “Dike Counts,” in either performing the upkeep or funding its servicing, they were severely fined and occasionally forfeited ownership rights.42 The costs of system monitoring, fines, and forfeited land ownership were borne by landowners and benefited the local water board, in accordance with the rules established

36 “The Zuiderzee and Delta Works of the Netherlands,” section entitled “The Afsluitdijk.”
39 Ibid.
40 Ibid., 361.
41 Ibid. Also, more on the Golden Era of the Netherlands at https://eh.net/encyclopedia/the-dutch-economy-in-the-golden-age-16th-17th-centuries/ (accessed 16 December 2016).
42 Ibid., 362-363.
by the collective to avoid a problem with free riders. Along with the local costs the individual landowners reaped the full benefit of additional land created by building new dikes, which created a unique economic situation in which the supply of land in the Netherlands is elastic. These factors tightened the linkage between dikes and land property ownership, but also resulted in a disjointed dike system that proved to be problematic in causing both an uneven level of security and of water distribution.

This apparent need for centralized authority and governance was addressed in the 1790s under the rule of a centralist Batavian Republic (1795), establishment of the national water agency (1798)—forerunner of the Ministry of Infrastructure and Environment—and finally the establishment of the Kingdom of the Netherlands (1815). As the form, function, and authority of the federal government evolved from the 16th to the 19th centuries, so did its primary source of revenue. Tax collection began as a system of fixed quotas by province (1583) and evolved into a system of progressive or regressive taxes based on income or luxury items or land, depending on whether the taxpayer was urban or rural (1670). Through the present time, the strength and transparency of the Dutch democracy have created a strong sense of accountability and has inculcated a path dependency of citizens willing to pay taxes for quality public services. The Netherlands exemplifies the theory that a foundation of trust in a representative government is a key factor in higher taxation rates, higher compliance rates, superior quality public institutions, and output that provides value for money that, in combination, result in an economically successful society.

Despite all of these advances and their many successes with water management, the Dutch were hit with another storm that resulted in catastrophe. On 31 January and 1 February 1953 a raging North Sea storm became the largest flood in modern Dutch history. The conditions of maximum storm surge peak coincided with spring tide high water bringing the total water level higher than ever recorded: 15 feet (4.57 meters) above mean

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43 Ibid., 363.
44 Ibid., 363-364.
sea level. It breeched 150 dikes, flooded more than 370,658 acres (150,000 hectares) of land, and overwhelmed local emergency response. The flood claimed the lives of 1,836 Dutch and tens of thousands of livestock (i.e., the farmers’ livelihoods), submerged 9% of the country’s farmland in saltwater, damaged infrastructure and buildings, caused the evacuation of 100,000 people, and left an indelible mark on the collective memory of the nation.

What went wrong? WWII contributed to the problem in that the Dutch coastal flood defenses had been neglected during the war and, after the war, the government prioritized post-war recovery over dike maintenance in a time of limited funds; thus the dikes were in disrepair and could not withstand the storm surge. The extensive damage they suffered caused catastrophic failure. Underlying that problem, however, was the Dutch reliance on large barriers to protect them from flooding. This storm epitomized the adage that “when large barriers fail, they fail catastrophically” that Dutch water managers and engineers now repeat as a warning to others when working with communities that are either developing a preventive adaptation strategy or rebuilding after disaster recovery. It is also a lesson that the U.S. had an opportunity to learn after the levees protecting New Orleans failed during Hurricane Katrina in 2005.

WWII also contributed to the solution because it had a strong effect on decision making. Rotterdam’s destruction in 1940 forced the Dutch to end their fight, to end their overt resistance, and to surrender to the Nazi enemy. It marked the beginning of a brutal five-year occupation culminating in the desperate ‘hunger winter’ of 1944-45 in which Rotterdam was one of the cities hardest hit, before liberation in May 1945. Thus, the

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wartime bombing and starvation made it unthinkable that the city and the country would not do everything in their power to fight back after being ravaged by the severe storm less than eight years later.

In his book about the uniqueness of the Dutch culture, Ben Coates offers evidence of how the relatively recent liberation of the Dutch from the Nazis at the end of WWII influenced their response to the 1953 storm. He cites examples of the military terminology used by official fundraisers for the survivors of the flood disaster, such as “the great counter-attack begins,” and “not an inch of land now taken by the sea in these floods will be given up.” The use of this narrative and framing tapped a familiar resolve that had sustained the Dutch during their occupation by Nazi Germany and redirected it toward another enemy—the North Sea. This “call to arms” activated, and infused with a sense of urgency, a communal mindset of determination and solidarity. It galvanized society-wide public commitment to collective action and signaled their willingness to financially and politically support yet another expensive public works project. The government vowed that never again would an extreme weather event find them vulnerable. They vowed to become weather proof. These strongly and defensively worded messages reinforced the current adaptation strategy of rigid resistance. The Dutch doubled down on hard line protection and any thought of retreat was rejected.

Following the Zuiderzee model, the Dutch appointed a Delta Commission to advise the government on execution of the Delta Plan that would concentrate on protecting the more vulnerable southwestern provinces while taking into account the economic imperative of keeping the ports of Rotterdam and Antwerp open. The Delta Act of 1958 changed the structure and administration of dikes and ensured the projects would be constructed to high quality and safety standards. The commission’s primary focus was on revamping and accelerating the ongoing Delta Works project—a series of new construction dams, locks, dikes, levees, sluices, pumping stations, and storm surge barriers as well as

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54 Ben Coates, Why the Dutch are Different: A Journey Into the Hidden Heart of the Netherlands (London, Nicholas Brealey Publishing, 2015), 38.
55 The Delta Works, in the section entitled “History,” Deltawerken online. Also Rosenberg, “Polders and Dikes of the Netherlands,” ThoughtCo. online.
reinforcements of existing barriers to shorten the Dutch coastline by almost half (see figure 5.2.).

Figure 5.2. Map of the Delta Works in Zeeland, The Netherlands.

The shorter coastline facilitated achieving the higher safety standards based on a risk approach that multiplied the probability of a flood occurring by the consequences of it occurring. For example, North and Central Holland were protected against the 1-in-1,000-year storm, the coastal regions to the 1-in-4,000-year storm, and the riverside areas against the 1-in-2,000-year storm. The major ports of Rotterdam, Amsterdam, and Schiphol were in the first category, while agricultural land was in the latter. The new price tag for the revised Delta Plan was €680-900 million and the commission estimated completion would take 25 years.

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56 The Delta Works, in the section entitled “History,” Deltawerken online.
58 Working together with water, Delta Commissie 2008, 40.
59 Ibid.
60 The Delta Works, in the section entitled “The Delta Commission,” Deltawerken online.
The federal government was simultaneously funding and managing two of the largest public works projects ever completed, as the repoldering of the Zuiderzee and the initial works on the Delta Works overlapped by 14 years. This was in addition to the billion-dollar cost of repairing and reconstructing infrastructure destroyed in the 1953 storm. Building on experience gained from the Zuiderzee Works, the engineers responsible for the Delta Works projects proceeded in a similar fashion to dam the Oosterschelde, Haringvliet, and Grevelingen estuaries to reduce the amount of exposed coastline and turn them into freshwater lakes, as was done with Ijsselmeeer. Public resistance to damming Oosterschelde, however, forced a change in the plan that would retain the saltwater environment by building a 1.86 mile (3 kilometer) long storm surge barrier—the longest in the world—that would remain open except in times of extreme weather. This single modification added cost and years to the project; this barrier alone cost €2.5 billion and it was not completed until 1986.

The culminating project of the Delta Works was the Maeslant Barrier; two gigantic, moveable storm surge barriers that are floated from their resting dry dock positions into the closed position, when a 9.84 foot (3 meter) storm surge is predicted, to protect Rotterdam and the surrounding area from flooding. The remainder of the time it remains open so as to not impede traffic in the Nieuwe Waterweg (New Waterway), the main shipping route into the harbor and port of Rotterdam. Each of the two moveable gates is 787.4 feet (240 meters) long, around the size and shape of the Eiffel Tower, making it one of the largest moving structures on earth, often referred to as the ‘eighth wonder of the world.’ This barrier took six years to complete (1991-1997), cost €450 million, and is shown in the closed, protective position in figure 5.3.

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61 “The Zuiderzee and Delta Works of the Netherlands,” in the section entitled “The Delta Works.”
62 Ibid.
63 The Delta Works, in the section entitled “Oosterscheidedam becomes a ‘kering,’” Deltawerken online.
64 Ibid.
65 The Delta Works. in “Measlanltkering” section.
66 Coates, Why the Dutch are Different, 36.
67 The Delta Works, in the section entitled “History,” Deltawerken online.
68 Ibid.
Not surprisingly, Delta Works took longer and cost more than was expected—17 years longer with a total cost of nearly €5 billion—but it is complete, is fully functional, has been tested and proven effective, is being maintained, and was fully funded and scandal-free.70

Once Rotterdam was thoroughly protected, the Dutch moved on to their next engineering project: the Maasvlakte 2 port expansion project. As the busiest port in the EU and the third largest port in the world, Rotterdam is critically important as one of two transportation hubs that support the bulk of the Dutch national economy—Schiphol airport is the other critical Dutch hub.71 Weather proofing provided both physical safety and economic security, and physical growth facilitates economic growth. The seaport has been expanded significantly over the years since its origins as a settlement on a small peat river in the 14th century, but it was nearing its operational capacity at 400 million tons of cargo in 2009.72 Maasvlakte 2 (Meuse River plain) plans to add 2,000 acres (809.37 hectares) of reclaimed land, doubling the port’s capacity, and a 65.62 foot (20 meter) deep wharf to accommodate the largest container ships, 73 (see figure 5.4.).74

70 The Delta Works, in the section entitled “Importance of the Delta Works,” Deltawerken online.
Work on the phased expansion project began in September 2008 and is expected to be complete in 2030 at a total cost of €2.9 billion. Sustainability is a key guiding principle and Rotterdam Port Authority’s (RPA) goal for all new construction terminal operations is zero carbon emissions. Since the port is expanding westward into the North Sea, newly installed wind turbines can tap the abundant wind power to generate electricity. RPA is encouraging and facilitating a “modal shift” from truck to inland barge and rail transport to further reduce carbon emissions. The first phase of the project was completed on schedule, and under budget by €150 million (i.e., actual cost of €1.55 billion rather than the planned cost of €1.7 billion). Phase two is planned and will be executed once demand surpasses current capacity.

This long historical pattern of reacting to extreme storm-related floods by implementing hydraulic engineering solutions to remove and keep the water out of their land shows how deeply entrenched was the Dutch adaptation strategy of water proofing. This changed in 2007. The new circumstances of climate change bring accelerating SLR, further land subsidence, more frequent and severe rainfall, warmer temperatures, and periods of drought. For example, the Dutch have experienced 7.87 inches (20 cm) of SLR along their North Sea coast in the 20th century, but are looking at a relative SLR of 2.13-4.27

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76 Ibid.
feet (0.65-1.3 meters) by 2100, a 300% increase from the past century if the most conservative estimate is accurate.\textsuperscript{79} Figure 5.5 shows as white the areas of the Netherlands that are below sea level as of 2016. This map depicts the Netherlands as a country that serves as a barrier to the continent. SLR represents a new, chronic, gradually worsening and potentially endless hazard of flooding that the Dutch recognized as being well beyond their usual engineering solution—it required a completely new strategy of adaptation.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{netherlands_map.png}
\caption{Map of the Netherlands depicting land below sea level.\textsuperscript{80}}
\end{figure}

As they have done in the past the Dutch government mandated another Delta Commission (i.e., the Sustainable Coastal Development Committee),\textsuperscript{81} enacted another Delta Act to embed the Programme in their political system and legal framework.\textsuperscript{82}

\textsuperscript{79} Working together with water, Delta Commissie 2008, in “Costs and Benefits of the Zuiderzee Works” section, 25. Relative SLR estimates are based on estimated high and low temperature increases from the 2007 IPCC report, glacial isostasy, and subsoil compaction.

\textsuperscript{80} Image credit: Worldatlas.com © 2018. See Appendix A - Permissions.

\textsuperscript{81} Stead and Taşan-Kok, “Urban Resilience, Climate Change and Land-Use Planning in Rotterdam,” 218.

\textsuperscript{82} Working together with water, Delta Commissie 2008, 13.
and created a Delta Programme that is the Delta Plan for the 21st century. Although the process, decision makers, and stakeholders were the same, there was a paradigm shift in adaptation strategy. The shift from reducing losses to choosing change ushered in a broader, more holistic strategy of water safety, sustainability, and adaptive delta management (2007) with a focus on preventive measures and behaviors, rather than reactionary measures following disaster recovery. Water safety is defined as including “people (flood casualties prevention), protection of economic, ecological, and cultural heritage values, preventing harm to our country’s international reputation, and preventing social disruption.”83 They articulated this in the philosophy of the Dutch Vision on Climate Change: “to adapt, prepare, and prevent through cooperative collective action” and built a much more robust strategy of adaptation.84 The Dutch shifted from weather proofing to climate proofing.

The Delta Programme differs from past Delta Plans in three fundamental ways: scope, duration, and funding. The expanded strategic scope includes the supply of adequate, high quality freshwater, which is threatened by saltwater intrusion from SLR and land subsidence;85 spatial planning, which addresses urbanization, commerce, industry, agriculture, nature, landscape, and leisure activities;86 and new flood protection standards based on the relevant effects of climate change, specifically SLR, reduced river discharge, and heavier rainfall.87 Frameworks that incorporate climate change in their approaches on freshwater supply, spatial adaptation, and flood risk management were rolled out in 2014 after four years of collaboration between all public, commercial, and private stakeholders. Underscoring each is the linkage of development with the changing climate—this is a full embrace of structural and non-structural accommodation.88

83 Ibid., 41.
87 Working together with water, Delta Commissie 2008, 10.
88 Ibid., 39.
The second difference is that, unlike the previous Plans that ended with completion of the final engineering projects, the Delta Programme is without an end date and their strategic outlook is to 2050, 2100, and 2200. The Programme’s work is ongoing, builds on its original twelve recommendations from 2008 and, after each annual progress report to the Cabinet, its recommendations (i.e., “Delta Decisions”) are fully integrated into all aspects of national policy, legislation, and their administrative agreements (2014) with regional and local authorities.  

This top-down governance approach is an effective method of synchronizing strategy, planning, and financing through the three tiers of government where a hole in any one municipality’s dike could prove disastrous for the entire small country.

The third change is that the Delta Programme has a dedicated Delta Fund with an annual budget of €1.2 billion through 2030, with an additional €0.1-€0.3 billion a year for beach nourishment, and a comparable annual funding anticipated through 2100. For clarification, the Delta Programme costs are in addition to an annual expenditure of €1.2 billion a year to maintain and manage existing flood protection and the fresh water supply. There are three noteworthy aspects of this financing. First, the government started with an estimate of national wealth that is at risk from flooding to understand what capital assets needed to be insured and protected. Sixty five percent of the €2,750 billion national wealth, which in 1997 was five times its GDP, means that €1,800 billion of the Netherlands’s capital lies in flood-prone areas. This puts into economic perspective the investment of insuring what is at stake based on their risk assessment. Second, financing will be through borrowing, such as through government long-term bonds, and natural gas revenues, the latter of which makes the useful connection between fossil fuel consumption, climate change, SLR, and the costs of flood protection. Local governments, non-governmental organizations (NGOs), and private parties are all considered viable.

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89 “What is the Delta Programme?” Delta Programme Commissioner, online in section entitled “Proposals for Delta Decisions.”
90 Working together with water, Delta Commissie 2008, 73.
91 Ibid.
93 Ibid., 81-82.
contributors to the Fund, especially where value and economic opportunity are added locally.

Climate change was the impetus for the Dutch to do more than just broaden their adaptation strategy from a plan that reduces losses to a more comprehensive program to choose change. In climate change, the Dutch recognized an economic opportunity to export their expertise on water safety to a new market of coastal cities at heightened risk of acute and chronic flooding. TCNs have been a key conduit for that exportation and Rotterdam has been a leader among networked delta cities. At the 2008 C40 Cities’ annual meeting in Tokyo—the first to address adaptation rather than just mitigation—Rotterdam led the eight other delta cities present in forming the Connecting Delta Cities sub-network under the C40 Cities Water and Adaptation initiative. Rotterdam was also one of the first cities selected for membership in Rockefeller Foundation’s 100 Resilient Cities. The Dutch port city maintains its leadership role in both networks as a critical source of information, knowledge, and technical expertise on building resilience by freely sharing its adaptation and mitigation strategies. The former (i.e., adaptation) is the city’s Water Plan 2—an update of the Water Plan 2000-2005—that describes its vision of “Rotterdam Water City 2030” and charts a course for a sustainable future by tightly linking water and spatial development in decision making to produce a cohesive urban planning process. The latter (i.e., mitigation) is the 2006 “Rotterdam Climate Initiative” that establishes a goal of reducing CO₂ emissions by 50% by 2025, which is more ambitious than the national plan and one of the most developed carbon capture and sequestration projects in Europe. Both strategies exemplify collaborative efforts between stakeholders in the city, port, and industry working together toward shared goals.

So, although the Dutch have exported their hydrological engineering expertise for decades, the advent of climate change and emergence of TCNs have broadened their

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expertise to include a more comprehensive strategy of accommodation and the process of collaborative decision making among stakeholders that garners success. They have commodified building resilience to the hazards of climate change that global port cities increasingly face.

This narrative describes the thousand-year relationship of the Dutch with their country, the North Sea, and the three rivers—Rhine, Meuse, and Schelde—that form the estuary in which the Netherlands is situated. Almost uniquely, the Dutch created and protected land from the sea and that process created a communitarian society adept at collective action. Although this study is on global port cities, not nations, the small size of the Netherlands makes it essentially impossible to distinguish Rotterdam’s policies from the nation’s policies until post WWII. Since then, however, as the port city realized its global status and TCNs endowed it with further agency, it is apparent that Rotterdam is an ideal case study for the adaptation strategy of climate proofing.

**Analysis: The Dutch Masters**

As with Venice’s adaptation strategy analysis, I will start by analyzing the interaction and effects of the six independent study variables—SLR-related hazards, risk tolerance to the hazard, influence of special interest groups, financial capacity, federation structure, and TCN membership—on the decision-making process for flood protection. I’ll address questions about the city’s resilience and intersperse a comparison of the evolving Dutch model of weather proofing to climate proofing with emphasis on hard-engineered measures to the Venetian model of behavioral modification to reduce losses and draw out similarities and differences.

The hazard to Rotterdam and the Dutch tolerance of that risk are a good place to start. Draining the swamp, or moors, and building one of the most densely populated countries in the world (i.e., population density of 503 people per square km, 2015)\(^7\) on land that lies at or below sea level and on the coast of a tempest North Sea have created a flooding hazard, a sensitivity to risk, a culture of adaptation, and a society perpetually focused on reducing their vulnerability to environmental risk. The change in climate that

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brought milder conditions favorable to large-scale agriculture (circa 1000-1800) was one of the original enablers of economic growth and social change (i.e., urbanization, population growth, and prosperity). At the same time these factors both degraded the environment and exposed more people to a flood hazard already inherent in life in the Netherlands.\footnote{Tol and Langen, “A Concise History of Dutch River Floods,” 360.}

The nature of the Dutch flooding hazard, until 2007, was characterized by abrupt and catastrophic flooding resulting from North Sea storms in contrast to the Venetian’s chronic and gradual flooding hazard. Both cities used an approach of \textit{reducing losses} to their hazards although they implemented different options and measures. The Venetians adjusted their behavior to the tides and considered the flooding risk tolerable, while the Dutch built hard-engineered defenses to very high standards of storm flood protection that reflected their extreme risk aversion. Specifically, the first Delta Committee required hydraulic engineering works be built to protect infrastructure against the 1-in-1,000-year flood and to protect life against the 1-in-10,000-year flood, with some regional variation.\footnote{Working together with water, Delta Commissie 2008, 40.}

These flood protection standards were, and remain, the highest in the world, and the Dutch have since raised them.

When the second Delta Committee was established and tasked in 2007 to address the hazards and risks to the Netherlands associated with the current changing climate, their report included three noteworthy findings. First, the fundamental nature of the hazard changed. The scope of the threat of flooding was broadened to include chronic and gradual flooding from SLR and heavier rainfall in addition to storm-related flooding.

Second, the magnitude of this new hazard necessitated a paradigm shift in thinking and the development of a significantly new strategic approach to a sustainable relationship with the environment. A shift was made from defending against the sea with larger, heavier, and stronger dikes alone to including behavioral modifications that mitigated the cause of global warming, conserved the supply of freshwater, and coupled development with sustainability. To this end, the municipalities and country established ambitious targets for GHG emissions, expanded reservoir capacity protected against saltwater
intrusion, built absorbent landscaping and infrastructure, and modified land use policy and spatial planning to decrease future exposure to flooding.

Third, the level of flood protection was increased to the point where the probability of catastrophic dike failure is virtually zero, reflecting a lower risk tolerance than before. The revised approach expanded on the first Delta Committee’s protection standards that were based on economic damage and casualties to include a combination of the individual probability of fatality, the probability of large numbers of simultaneous casualties, and the potential damage beyond just economic loss. The Committee’s goal was to equate water safety standards with the standards for other hazards that protect human life by setting the individual or local risk level at 1-in-a-million.

Also worth noting is what did not change, which moves into an analysis of the other independent variables. There were no new stakeholders or special interest groups introduced to the decision making that resulted in adopting a new adaptation strategy, which meant the deeply institutionalized process remained the same. The Dutch did not seek external assistance and the lack of unsolicited external interference is a testament to three factors, all of which pertain to the effectiveness of the Dutch government. The first factor is the long history of successful water management by the government that, although centrally controlled at the federal level, is thoroughly integrated with regions and cities. Since the country is small and almost completely flood prone, the flood risk affects everyone directly or indirectly requiring all levels of government to cooperate to ensure an overall cohesive effort without overlap or gaps. This collective action is rooted in the Dutch history that even predates the formation of the Kingdom of the Netherlands, to include a time when the provinces worked together in various political arrangements toward common goals and developed strong norms of community. This polycentric governance and path dependency have earned the Dutch government a level of credibility that external interest groups do not question.

Second, throughout their history the Dutch have had a governance system of strong civic participation, accountable representation, and transparency that created a high level

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100 Ibid., 10.
101 Ibid., 41 and 88.
102 Ibid., 42.
of trust between the governed and their governors.\textsuperscript{103} Society is deeply concerned about water safety and the government’s prioritization of flood protection as a “paramount collective good” reflects the healthy representative nature of the democracy.\textsuperscript{104} Its past record on water management and continued deliverance of quality public service sustain this relationship and dispel potential agitation from internal interest groups.

Third, the first two factors empower the government’s relatively high income taxation rate (i.e., 37.8\% in 2015) and solicitation of investment financing that contribute significantly to their financial capacity to fund large public works projects.\textsuperscript{105} More financing is obtained from revenue from the natural gas sector, an industry targeted by the second Delta Committee as an appropriate source for the Delta Fund. Appropriate, as explained in the Committee’s report, because of the direct causal linkage between fossil fuel consumption, climate change, SLR, the hazards of chronic flooding, and the costs to protect the county, which are the costs of the Delta Programme.\textsuperscript{106} Further, based on this causal relationship, the new adaptation strategy recommends a decrease in fossil fuel consumption and a transition to renewable energy sources, despite the GON’s revenue from the natural gas sector.

There is a digression worth taking here to discuss the lack of politicization of a climate change issue in the Netherlands that is highly politicized in other fossil fuel producing countries. Why is this? Why would a government publicize the local detrimental effect and incentivize its society to decrease consumption of natural gas while it owned the largest gas deposit in the EU? As will be discussed in the Miami case study section, this is not a common approach. It turns out that the Netherlands’ discovery and extraction of natural gas has been both a blessing and a curse. The sector generates GDP and jobs for the Dutch, and a secure source of energy for the EU. For example, in 2005 natural gas represented 7\% of Dutch GDP and supported 66,400 full-time equivalent direct, indirect,

\begin{itemize}
\item \textsuperscript{103} Prak and van Zanden, “Tax Morale and Citizenship in the Dutch Republic,” 1-3. In their study the authors argue that citizenship arrangements and the positive incentives of democracy, fairness, and value for money resulted in high tax compliance in western societies.
\item \textsuperscript{104} Working together with water, Delta Commissie 2008, 118.
\item \textsuperscript{105} OECD Revenue Statistics 2016 https://www.oecd.org/tax/revenue-statistics-netherlands.pdf (accessed 7 January 2017). The Government of the Netherlands is ranked tenth highest of 35 OECD countries in tax-to-GDP ratio in 2015. Denmark was first with 46.6\%, the U.S. was 31\textsuperscript{st} with 26.4\% and Mexico last with 17.4\%.
\item \textsuperscript{106} Working together with water, Delta Commissie 2008, 81-82.
\end{itemize}
and induced jobs.\textsuperscript{107} More recently natural gas provided 9% of state income (2013), although that decreased to 3% in 2015.\textsuperscript{108} On the other hand, the discovery of the world’s tenth largest gas field in Groningen and infusion of foreign income wreaked havoc on their economy in the 1960s—\textit{Dutch disease}—and the extraction causes land subsidence, exacerbates SLR, and is now causing local earthquakes.\textsuperscript{109}

Rather than myopically focusing on maximizing short-term gains by selling its 940 billion cubic meters of reserves,\textsuperscript{110} the government is dramatically scaling back production and using revenue to transition to renewable energy. If the Exxon Mobil and Royal Dutch Shell joint venture that operates the Groningen gas field disagrees with or feels threatened by the Dutch government’s dictate to slash production, it has not expressed dissent.\textsuperscript{111} The joint venture could have been an internal agitator to stymie both the curtailment of gas production and the inclusion of bold and clear statements about fossil fuel and climate change in the 2008 adaptation strategy. Two factors may contribute to this non-event. First, Dutch political campaign finance laws may restrict corporate donations which would leave Dutch politicians less beholden to donors. In this case the natural gas industry would be less able to thwart mitigation efforts. Second, this may reflect the communitarian norm in which commercial stakeholders collaborate toward shared long-term objectives rather than obfuscate issues or obstruct change for short-term financial gain. The joint venture can transition to renewable energy provision.

A note on a rather unusual advantage that the Dutch have over others regarding financial capacity is their ability to create new land. As mentioned earlier, the elastic supply of land in the Netherlands is a consequence of their location on the coast of a shallow body

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\textsuperscript{107} \textit{Dutch Gas Sector: Overview of Research and Collaboration (2006-2009)}, NL Agency Ministry of Economic Affairs, Agriculture and Innovation, 6
\textsuperscript{108} The value of goods and services produced around the Dutch gas sector was €41 billion (7% of GDP). Also, “induced jobs” is the employment effect generated from spending the income from direct and indirect jobs in the broader economy.
\end{flushleft}
of water and a result of their poldering expertise. Polders are land and land creates opportunities and revenue, and that revenue can replace lost natural gas revenue.

As the above points highlight, the political system and financial independence are interdependent factors that prevent special interest groups from influencing the decision-making process for developing an effective adaptation strategy. From the perspective of the Panarchy framework these two factors exclude special interest groups and keep the multiscale decision-making process nested within a primarily Dutch group of public, commercial, and private stakeholders. In Venice, inadequate financial capacity, corrupt governance coupled with complicit commercial entities, and competing alliances of stakeholders enabled external special interest groups access that disrupted a weak decision-making process and produced a maladaptive change to their strategy. Although MOSE may have been an appropriate engineering solution to the Venetian hazard of extreme storm surge—and that has been challenged—it was inappropriate for their political, social, and economic institutions, and thus doomed to failure.

There may be another factor that contributed to the lack of infusion of special interest group influence in the Netherlands. Unlike the drama created by the 1966 storm that flooded Venice and aimed a spotlight on the Italian government’s inability to either manage the disaster recovery or assuage the art world’s fears of impending doom, the change in the nature of the Dutch hazard to chronic and gradual flooding was imperceptible and the discussion was internally controlled. The first external awareness of the new threat to the Netherlands was publication of the findings of the second Delta Committee in 2008.\(^\text{112}\) Thus the nature and scope of the flooding hazard appears to be a factor that combines with effective governance and financial capacity to limit the likelihood of unsolicited influence by special interest groups. These factors are opposite in the Venice and Rotterdam cases. Change from a primarily chronic hazard to one that includes abrupt hazards, ineffective and corrupt governance, and inadequate financial capacity in the Venice case as compared to change from a primarily abrupt hazard to one that includes a chronic hazard, effective and accountable governance, and ample financial capacity in the Rotterdam case. The correlation of these three factors (i.e., hazard type, governance,

financial capacity) with the level of effectiveness of the adaptation strategy may be anecdotal, or it may be a pattern.

The final study variable to address is the influence of TCN membership on the city’s decision-making process and resilience. Rotterdam is one of the more networked global ports in the world, yet TCN membership for them has been more financially advantageous than anything else. Their early membership in C40 Cities, status as the founder and continued leader of CDC, status as an original member in 100RC and other TCNs were based on their experience and expertise. 100RC refers to Rotterdam as a living resilience laboratory and it is one of C40 Cities Innovator Cities. These network connections, in addition to their bilateral connections with London, New York City, New Orleans, Venice, Jakarta, Ho Chi Minh City, Copenhagen, Hong Kong, Singapore, Abu Dhabi, and other coastal cities, has enabled an outward flow of knowledge and an inward flow of revenue. TCNs enable the Dutch commodification of their expertise on flood protection and freshwater supply, an opportunity they openly acknowledge based on a comment made by one of their engineering consultants that, “Water is where the economy meets the city,” when discussing the future of climate change on port cities.

Because of their expertise in water management it is unremarkable that Rotterdam’s city networking facilitates the spread of Dutch influence across state lines to other port cities. They are a knowledge source disseminating best practices to knowledge seekers. Less apparent is whether knowledge sources learn from their interaction with knowledge seekers and if that information influences their adaptation decisions. In this situation it can be argued that Rotterdam was influenced by their post-Katrina interaction with the city of New Orleans. Dutch hydro-engineers were called in to assist and saw first hand the catastrophic damage caused when the levees failed and 80% of the city was flooded. 1,836 people died in New Orleans; that is the exact number of deaths the Dutch experienced during the 1953 North Sea storm. Katrina struck in 2005 and within two years the Dutch announced a pivotal shift in adaptation strategy away from full reliance on built

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114 Quote of Tom McNeilan, Fugro Atlantic, at the Transatlantic Solutions to SLR Adaptation conference, Old Dominion University, 30-31 October 2013.
structures for flood protection. This is evidence city networking, whether via a TCN conduit or through bilateral exchanges, influences adaptation decision making.

How does Rotterdam as the case study for climate proofing contribute to my hypotheses testing? The first hypothesis is that C40 Cities favors engineered solutions over politically contentious behavioral modifications. My analysis indicates that Rotterdam perpetuates the flow of engineering business practices through the TCNs yet, uncharacteristically, does not seem to exhibit a politically motivated bias against the necessary behavioral changes required for an optimal adaptation to conditions of SLR. In fact, from exposure to conferences and academic venues I perceive a willingness by Dutch consultants to share freely all of their experiences and documentation to assist cities in decreasing their exposure to flooding hazards, regardless of their level of financial capability.

The second hypothesis proposes that networking among C40 Cities members will partially bypass the vertical blockage at the national level, but may also preempt development of a more locally inclusive adaptation strategy from the bottom-up. The Rotterdam case seems less relevant as a strong test of this hypothesis since the Netherlands federal government assists rather than obstructs Rotterdam’s initiatives. This hypothesis is better suited to knowledge seekers than knowledge sources in a network.

Hypothesis number three addresses the influence of abrupt events as necessary, although not sufficient, instigators of discontinuous change. In the case of Rotterdam this hypothesis is falsified—to an extent. The gradually increasing threat that climate change induced SLR posed was not an abrupt event in the physical sense to the Netherlands. However, as discussed earlier, hurricane Katrina was a distant catastrophic and abrupt event that likely became a catalyst for earlier change for the Dutch. Climate change was on their radar and the Dutch government’s predilection for prevention and extreme aversion to risk, in combination with New Orleans’ experience, prompted the sweeping change. Without Katrina the Dutch would have likely changed strategies, but Katrina probably moved up the timing of the policy shift. In fact, the second Delta Committee noted the Dutch government’s institutionalized bias toward preventive flood protection—in contrast to the UK and US governments’ focus on disaster management, insurance, and recovery—in its
report and recommendations for adaptation.115 Their desire is to avoid the extreme cost of future disaster recovery, the chaos that such costs inflict on the government’s budget, and the lost productivity and trauma of recovery.

This latter point was a lesson learned from their neglect of flood defenses over recovery efforts from WWII that contributed to the damage of the 1953 storm. The war had another effect, however, that turned out to be an advantageous, albeit unenviable, to the city of Rotterdam in rebuilding its port in a more resilient manner. The Germans razed the port city in a massive aerial bombing raid on 14 May 1940 to force the capitulation of the Netherlands. The bombing was a military success in that the Dutch surrendered to the Nazis, who then immediately occupied the country. However, the destruction of this vital port to Europe was total and rebuilding Rotterdam became a top priority of the Germans as well as the Dutch.116

From the perspective of this study the destruction of Rotterdam released the Dutch from the burden of whether to change their infrastructure to be more resilient. It was an instance of discontinuous change—breakage away from existing processes of gradual, incremental change—that facilitated a leapfrog to newer construction techniques for all of the port infrastructure and newer, more automated technology for cargo handling, intermodal transportation, and communications. The bombing was catastrophic, but the Dutch turned it into an opportunity for eventual economic gain. In this sense, WWII set the stage for Rotterdam’s unique contribution as a resilient global port that mastered weather proofing and has the institutionalized decision-making components for mastering climate proofing.

In conclusion, from a technical perspective their long history of experience has contributed to the Dutch becoming renowned hydrological engineers. From a social and political perspective the large scale of their engineering projects, to both reclaim and then

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protect the land, required the Dutch to work together as a community, which influenced their governance structure. And from an historical perspective the centuries over which these communitarian adaptation experiments took place resulted in the institutionalization of their relationship with each other, their relationship with the water, and their acceptance of change. The decision-making process of the Dutch adaptation cycle includes all scales of the Panarchy framework, from smaller decisions at a local level on a shorter timeframe to complex and phased decisions involving stakeholders at the local, regional, and national levels that spanned decades. These factors are the foundation of the Dutch resilience to change as exemplified in their port city of Rotterdam.

What the case of Rotterdam reveals is the specifics of how the definition of urban resilience can be realized in practice. Refer back to ACCCRN’s definition “urban resilience is the capacity of cities (i.e., individuals, communities, institutions, businesses and systems) to survive, adapt, and thrive in the face of stress and shocks and even transform when conditions require it.”117 This case study has shown that Rotterdam fits that definition well. Unsurprisingly, Rotterdam displays most of the characteristics identified in the literature on resilience that are considered necessary for resilience. Each of the ten characteristics—from effective governance and institutions, to a high degree of social and economic equity, to continual and effective learning—are displayed in Rotterdam’s decision-making process for adaptation.118 This is empirical evidence that links resilience theory and the behavioral theory of collective action, as was discussed in chapter two in the literature review on resilience theory.

Unlike Venice, Rotterdam has the capability to finance recovery, prevention, and adaptation measures and its ecological resources are of a nature that does not attract powerful special interest group interference. The beaches of the North Sea are not the same draw as the beaches of Miami, nor are UNESCO WHS polders capturing the same level of interest as UNESCO’s WHS Venice and its lagoon. Without those challenges the decision-making process for adaptation has remained intact, nested from small and fast to intermediate to large and slow (refer to figure 3.2. the Panarchy heuristic model of nested

117 Rockefeller Foundation’s ACCCRN, online, 2015.
118 Refer to this study’s chapter 3 section on the Dependent Variable: Resilience that refers to Bahadur, Ibrahim, and Tanner, “Characterising resilience,” 2013.
adaptive renewal cycles) within the bounds of the Netherlands without disruption from external power brokers. In fact, most exchanges of information and transaction flow outward and upward from Rotterdam to TCNs and international organizations or outward to bilateral municipal partners maintaining the traditions established by the Dutch East Indies Company or trade practices along the ancient Maritime Silk Road. The Dutch are information sources, not seekers, who aid others in their urban policy learning process. Finally, the Dutch case is an example of collective action, in that individuals are willing to pay higher taxes and accept dictated behavioral mandates for relocation from their government for the betterment of the common good. The case exemplifies collective action functioning in a democratic society with a strong capitalist economy.
CHAPTER 6

GUANGZHOU

Guangzhou is Innovating

Guangzhou, formerly Canton, is the third global port city to be studied based on its adaptation strategy. Unlike the examinations and analyses for Venice and Rotterdam, Guangzhou research is challenged by a lack of primary source, critical, non-government produced data available in English. The government-produced information is uniformly positive, uses questionable data, and does not provide insight to decision-making processes, the influence of special interest groups, or assessments of the effectiveness of adaptation measures.¹ Language poses another barrier. Case in point, the 900-page “Third National Climate Change Assessment Report” released in November 2015 would be a key data source of policy, however it was only available in Chinese and it was not free, which limits its distribution for potential translation. Thus, a thin body of literature and newspaper articles that summarize primary source data must be relied upon. This strict control of information hampers analysis, but China’s size and unique political economy—‘state-led, authoritarian capitalism’—contribute useful dimensions to my study.²

For millennium, farmers in the Pearl River Delta maintained a harmonious relationship with their environment that led to the growth of a city and major port on the Silk Road. Flooding was valued as part of the cycle of growth, although a rudimentary system of dikes was constructed as protection against damage from unseasonable rainfall.


Local management of the ecosystem flourished under dynastic rule, but the 20th century brought political and economic change that broke the historical pattern, wreaking devastation on the environment. Single-party authoritarianism and economic liberalization led to industrialization, population growth, and urbanization at a rate and scale, which, when combined with climate change, posed an existential threat to Guangzhou and other Chinese port cities. In response to this, the national government chose to reduce losses through an adaptation policy that combines innovative structural and non-structural measures to rebalance the social-ecological relationship. The national government retained centralized control of the “sponge city” program management, however, rather than empowering local stakeholders, which casts in doubt the city’s resilience.

The following description of Guangzhou will place the port city and its flooding hazard in political, economic, and historical context. The subsequent analysis of factors and interactions will include a comparison of Guangzhou with Rotterdam and Venice.

Description

Guangzhou (Gwan-JO) has much in common with Venice and Rotterdam, such as its deltaic location, status as a key port city, history of flooding, and vulnerability to SLR, although these characteristics and issues are on a much bigger scale. Guangzhou is situated in the estuary where four river systems—the Xi, Liuxi, Bei, and Dong Rivers—join and become the Pearl River before flowing 90 miles out into the South China Sea (see figure 6.1). As this map shows, like Rotterdam, Guangzhou is not a coastal city, whereas Venice is. Guangzhou’s location on the water made it an ideal settlement and port that was valued by the regional feudal state dating from the Zhou dynasty (1146-771 BC). Since the third century it has become an increasingly important trading port on the Silk Road connecting China with early Muslim traders and then the succession of European maritime powers and traders—the Portuguese (early 1500s), the Dutch and British (17th century), and the

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French, Americans, and other foreign nationals. Silk, paper, gunpowder, spices, influence, philosophy, religion, culture, language, inventions, wealth, and disease were transported via these early routes of international trade and its major ports gained in importance beyond their local area. Guangzhou, romanized by the Portuguese as Canton, grew and is now a key transportation, industrial, financial, and trade center of southern China and a key node in the global economy.

![Figure 6.1. Pearl River Delta of southern China.](image)

As was the case with Venice and Rotterdam, the Chinese meddled extensively with the local environment to build, expand, and maintain an urban center and port at the head of the river delta. The silt flowing from the rivers was of such a magnitude that it narrowed

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5 Ibid.
the original 2,000-meter wide ‘Pearl Sea’ to the current 180-meter wide Pearl River channel.\(^8\) The original port city relocated south periodically to retain its waterfront on the Pearl River delta until construction technology enabled the Chinese to dredge accumulating silt and keep the deep-water ports open for shipping. From the vantage point of its functionality as a port the Chinese have been effective in combatting this force of nature for economic gain.

Guangzhou Port Group is now one of China’s largest port complexes, linked by rail to the north, east, and west, with an advanced highway system throughout the metropolitan area, and it is proximate to the largest airport in southern China.\(^9\) In 2014, Guangzhou’s container shipping volume was 16.16 million TEU\(^10\), and its total cargo shipping volume was 500,975 metric tons earning the port a ranking of third and eighth, respectively, in the world in those categories.\(^11\) The Pearl River Delta port area is the primary region for wealth and advancement in Guangzhou city, thus linking the delta to Guangzhou’s identity in the same manner that Venice’s identity is linked to its lagoon.\(^12\) It is of critical importance to China.

A closer look at this picture of economic vibrancy, however, uncovers two interrelated factors that put the city and port at a high level of risk and threaten its future economic viability: urbanization and climate change. The first phenomenon started gradually with industrialization in the mid-1950s, but its pace picked up in the late 1970s when the Communist Party of China (CPC) shifted national policy toward economic liberalization—market socialism.\(^13\) The policy change spurred a massive migration from the countryside to cities by citizens seeking the economic opportunity associated with a freer market and privatization. In 1978, less than 20% of the Chinese population lived in

\(^8\) Weng, “A historical perspective of river basin management...,” 1049-1050.
\(^9\) Gong-fu and Kuo, “Guangzhou, China,” 1 November 2016.
\(^13\) Coase and Wang, “How China Became Capitalist.”
cities, but by 2015 56% of the population was urban based, and that is projected to continue to increase to 60% by 2020. Existing cities grew without centralized urban planning, regulation, or oversight and new cities were built at an unmatched rate at the expense of quality and sustainability with the environment. In 2009 there were 221 cities in China with populations over one million; the magnitude of which becomes apparent in comparison to the 35 cities of that same size in all of Europe.

Guangzhou is an example of a delta city that experienced extensive and fast-paced urbanization during the period of economic transformation. The province within which Guangzhou is situated, Guangdong, is the most popular immigration destination in China, with 20 million people from outside the province living there. In 1970, Guangzhou’s population was 1.54 million and 45 years later it was 12.46 million, making it the largest city in South Central China and the third largest city in China. The rate of the megacity’s population growth from 1970-2015 was 800% compared to China’s overall population increase of 59% during the same time period. Thus, the mass migration to Guangzhou greatly increased the scale and degree of exposure of its population to flooding.

The infrastructure to accommodate the urban immigration relied heavily on the use of cement, reflecting China’s lack of lumber resources and keeping in step with the global trend away from steel to cement in building materials. The relative scale and rate of cement usage by China was noted by Bill Gates, who said that China used more concrete between 2011-2013 than the U.S. did in the entire 20th century—6.6 gigatons compared to

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15 Ibid.


19 Swanson, “How did China use more cement...” The growth in steel production increased by a factor of 8 compared to a factor of 25 for cement from 1950-2010.
4.5 gigatons.\textsuperscript{20} The boom in urbanization and the expanding usage of cement benefits China economically because 50% of the world’s cement is produced in China and cement production is government owned.\textsuperscript{21} However, there are problems associated with its overuse and the cost of mitigating those effects is rising. As highlighted earlier, cement’s impermeability exacerbates urban flooding; its production is a significant source of air pollution; and it accounts for up to 5% of carbon dioxide (\(\text{CO}_2\)) emissions, which contributes to climate change.\textsuperscript{22} Flooding increased in frequency and severity because the urban expansion above ground outpaced the infrastructure construction underground that is necessary for drainage, sewage and wastewater treatment, and flooding protection.\textsuperscript{23} This reflects a lack of urban planning that has not gone unrecognized by the locals. For example, residents in Guangzhou blamed an inadequate drainage system that was unable to handle the heavy rains in May 2016 for the extensive flooding damage they suffered.\textsuperscript{24}

This leads to the second factor contributing to the flooding hazard that Guangzhou faces—climate change. The findings of the 900-page “Third National Climate Change Assessment Report” released by the Chinese government in November 2015 convey a dire situation.\textsuperscript{25} All of the usual effects—warmer temperatures, less frequent but more intense rainfall, more frequent and more intense storms, longer and more severe droughts, and accelerated SLR—are forecast to affect China, but to an extent greater than the global averages, as is the case with Asia in general. Specifically, both the actual SLR from 1980–2012 in China, 0.11 inch (0.29 cm) a year, and the projections of 16–24 inches (40–60 cm) SLR by 2100 on China’s east coast are higher than the global average.\textsuperscript{26} For Guangzhou and other east coast low-lying deltaic cities, one centimeter in vertical rise brings the sea inland

\begin{itemize}
\item \textsuperscript{20} Ibid. One gigaton is approximately one billion metric tons. Author cites and explains the facts behind Bill Gates’ statement.
\item \textsuperscript{21} Ibid.
\item \textsuperscript{22} Ibid.
\item \textsuperscript{23} “Factsheet Sponge City Construction in China,” Government of the Netherlands, 2016.
\item \textsuperscript{25} The report was released by the Ministry of Science and Technology, is only available in Chinese, and is not free. Findings cited are from news articles about the report.
\end{itemize}
ten meters. Although this projection range for China’s SLR is just half of the projection for the Netherlands—0.71-1.42 yards (0.65-1.3 meters) by 2100—the Chinese cities do not have engineered defenses in place to the scale of their hazard, which makes their exposed delta and coastal cities more vulnerable than Dutch cities. A study conducted 20 years ago predicted that Guangzhou’s high tides—maximum tidal range of 2.88 yards (2.63 meters)—and SLR would combine with storm surges and flood the city more often and more severely, and that prediction has been validated in the past two decades as the existing 2.19-yard high (2 meter) dike system proves to be inadequate for the changing environmental factors. Guangzhou’s flooding can now be categorized as nuisance with periodic black swan events.

Thus, China’s economic reform toward liberalization increased industrialization and urbanization that generated mass migrations, extensive construction, energy consumption, ground water extraction, and pollution that resulted in a severely degraded environment throughout much of China. According to a 2017 Council of Foreign Relations article, the state of China’s environment is dangerous. Two-thirds of its cities have inadequate and contaminated water, one-quarter of its rivers are “unfit for human contact,” it is experiencing rapid desertification, 80% of its cities failed to meet air pollution standards for most of 2015, and its consumption of 50% of global coal—underreported since 2000—enabled China to contribute 27% of the world’s GHG in 2014 with less than 20% of the world’s population. The effects of this environmental depredation are felt most acutely locally, but due to China’s scale its pollution contributes significantly to global warming. As the most populous country and the largest producer of GHGs, China’s contribution to

27 Buckley, “Chinese Report on Climate Change...”
28 Working together with water, Delta Commissie 2008, 25. Relative SLR estimates for the Netherlands are based on estimated high and low temperature increases from the 2007 IPCC report, glacial isostasy, and subsoil compaction.
31 Ibid.
climate change is significant.\textsuperscript{32} Local effects can be measured economically, socially, and politically. Economically, environmental depredation is estimated to cost China 3-10\% of its annual gross national income.\textsuperscript{33} Socially, the pollution directly affects residents' health, life expectancy, quality of life, and access to natural resources, and is considered the cause of growing unrest as expressed in "mass incidents" ranging from peaceful protests to rioting.\textsuperscript{34} Lastly, the economic costs and social unrest challenge China’s political leadership, and that challenge is taken seriously by the CPC.\textsuperscript{35} Authoritarian regimes are characterized by demanding strict obedience to the state, and the CPC has a history of employing oppressive measures to quash social agitation.

The evidence of pollution and climate change portrays a bleak situation for all of China, but for Guangzhou, which is part of the 13\% of the Pearl River delta that is below sea level, the threat is existential.\textsuperscript{36} Beyond its ranking as one of the biggest container and total cargo ports, the Guangzhou Port Group tops the charts in other rankings. In an analysis of the exposure of population and assets to coastal flooding of 136 global port cities, Guangzhou ranked second highest with 2.7 million of its 2005 population of 8.4 million (32\%) deemed vulnerable, and the city maintains that ranking although its population at risk in the 2070s is projected to rise to 10.3 million people.\textsuperscript{37} Although they fared better in 2005 in comparison to other global ports (i.e., ranked 11\textsuperscript{th}) for the value of their assets that were exposed to flooding, the OECD report projects a 4,000\% increase in exposed assets to a value of $3.4 trillion in the 2070s.\textsuperscript{38} This exponential increase in exposure is attributed to climate change, man-made land subsidence, population density growth, their low level of flood protection, and a higher asset valuation in port infrastructure from 2005 to the

\textsuperscript{32} Ibid.  
\textsuperscript{33} Ibid. The wide range of 3-10\% reflects various estimates. Due to its sensitive nature the Ministry of Environmental Protection only releases figures intermittently.  
\textsuperscript{34} Ibid.  
\textsuperscript{35} Ibid. Authors cite CSIS analysts Jane Nakano and Hong Yang.  
\textsuperscript{36} Shannon Bond, “How Cities are revamping their coastal defenses: Rising sea levels present the biggest challenge for low-lying cities such as New York, Mumbai, and Guangzhou,” Financial Times. 5 September 2014.  
\textsuperscript{37} Nicholls et al., “Ranking Port Cities...,” 7-8 and 28. Exposure is calculated based on exposure to a 1-in-100 year flooding event. 
\textsuperscript{38} Ibid., 30.
2070s. The historical valuation of Asian port infrastructure (excluding Japan and Singapore) was typically lower than the valuation of port infrastructure in fully developed nations, such as those in Europe and North America. If the recent, relatively higher economic growth in developing Asian countries continues as expected, it will have a leveling effect on future asset valuation across many nations, including China.

Further analysis of the data on Guangzhou's exposure, vulnerability, and risk that focused on disaster risk management classified the city as the most vulnerable of the 136 global ports. The authors of the 2008 OECD report used a standard industry metric—economic AAL—and took into account Guangzhou's potential flood risk based on the combined vulnerability of its population and infrastructure assets and the existing flood protection and assessed annual losses as $687 million in 2005 and then projected the AAL to be $13,200 million in 2050.

Who will bear these costs and what is their risk tolerance? An annual economic loss in the hundreds of millions or billions of dollars for Guangzhou, one of several mega cities and port cities in China, will damage the local and regional economies and reach into the national coffers. The actual distribution of costs across the layers of government and between the sectors of society is unclear because China's ruling political party, the CPC, limits information dissemination.

Notwithstanding this opaqueness, and keeping in mind that risk tolerance is influenced by financial capacity, the 2011 study that ranked global ports provides a gauge we can use. The authors compared the financial capacity of countries with global port cities, using per capita GDP as the metric, and evaluated China as lying in the middle range between risk averse and risk tolerant countries. That middle categorization places it in the ‘presumed protection standard’ of being ‘able to afford to construct defences but not to a uniform, high standard.’ Although Guangzhou was not included in this 2011 study, Shanghai was, and my assumption is that the level of flood protection for all Chinese port cities is about the same based on the People’s Republic of China’s (PRC’s) centralized

\[\text{\textsuperscript{39}} \text{Ibid., 18.}\]
\[\text{\textsuperscript{40}} \text{Hallegatte et al., "Future Flood Losses...," 2-3. The flood risk level is to the 1-in-100 year flood. Tables 1 and 2 for 2005 and 2050 AAL estimates, respectively. 2050 projection uses a scenario that includes socio-economic change, subsidence, SLR and adaptation to maintain flood probability.}\]
\[\text{\textsuperscript{41}} \text{Hanson et al., "A Global Ranking of Port Cities...," 106, Table 5.}\]
decision making. Shanghai’s protection level (1:1,000) indicated a higher risk aversion to flooding than New York City (1:100), despite its lower financial capacity, but a lower risk aversion than Rotterdam (1:10,000). London and Tokyo had the same protection level of 1:1,000 as Shanghai. Thus, the lack of correlation between financial capacity and level of protection is one gauge that indicates China’s relatively lower risk tolerance to flooding which manifests as its *willingness to protect*—good news for Guangzhou.

China’s willingness to protect took on a new dimension in 2011 when China, for the first time, acknowledged to its domestic audience the impact of climate change and included climate adaptation in its 12th 5 Year Plan, “National Social and Economic Development Plan 2011-2015,” which was followed in 2014 by promulgation of the “Technical Guideline for Sponge City Construction.” In his address to the UN General Assembly session in 2015, President Xi Jinping committed China to becoming a global leader in tackling climate change, essentially executing a reversal of China’s policy of denial. He described the risks associated with climate change and laid out a strategy that included mitigation and adaptation policies to transform China into an “ecological civilization.” The government’s ecological reforms aimed at balancing the relationship between society, the economy, and the environment.

In fact, the government’s aim is more accurately a re-balancing of the harmonious relationship that the early Guangzhou settlers and farmers in the Pearl River Delta had with their environment for thousands of years. Feng shui, the philosophy of placing man-

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42 Hanson et al., “A Global Ranking of Port Cities…,” 104-106. Also, the comparative metric in parenthesis is the return period of the flood event. For example the 1:1,000 refers to a standard of flood protection against the 1-in-1,000 year event. See Nicholls et al., “Ranking Port Cities…,” 32-33.
43 Nicholls et al., “Ranking Port Cities…,” 33, Table 6.
47 Weng, “A historical perspective of river basin management…,” 1048.
made forms in harmony with nature, was used in the original placement of the ancient city at the mouth of rivers on the delta. This philosophy is very similar to the adaptive management “flows with nature” concept advanced by Berkes and Folke that uses local ecological knowledge, promotes local self-organizing and learning, and values resilience and sustainability. In ancient Guangzhou, locals managed river basins and used water in a sustainable manner by gradually building dikes and reclaiming land for agricultural expansion without disrupting the balance of the ecological system. In his account of traditional dike building and land reclamation in the Pearl River Delta, the author Weng cites the “elegant” technologies used by the locals for water and soil conservancy—elegant “in that they showed a great understanding of the people-environment interactions” that remain relevant today for the Pearl River Delta and similar deltaic settings around the world. Specifically, farmers followed an environmentally conservative, three-stage process of depositing rocks, planting reeds, and building dikes that took 4-10 years, during which time the quasi-aqueous delta was dried out for agricultural use, without the use of pumps, and then protected from flooding. The three relevant points of this historical land use example are that the process was slow, locals developed it, and it proved durable. These three characteristics reflect a resilient adaptation process in a dynamic socio-ecological relationship.

This harmonious relationship was disrupted in modern-day China when the central government announced ambitious economic reform policies of industrialization and urbanization that required a larger quantity and faster pace of dike construction and seaward extension of the delta area. There was no time for feng shui. The new, engineered public works projects supplanted the conservative and more evolutionary, locally developed process, causing extensive damage to the environment and increased flooding.

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48 The Professional Register for UK and European Feng Shui Consultants. http://www.fengshuisociety.org.uk/about-feng-shui/history-of-feng-shui/ (accessed 19 January 2017). Feng shui translates as wind-water and is an ancient Chinese discipline that continues to be an important aspect of Chinese culture, although Communism is considered to have quashed it.
51 Weng, “A historical perspective of river basin management...” 1061.
52 Ibid., 1049.
53 Ibid., 1057.
The top-down driven reforms also took away the locals’ authority to manage their land use, and it took away their responsibility.

As explained in the urban ecology literature, “urban infrastructure mediates the relationships between human activities and ecosystem processes and may exacerbate or mitigate human impact, depending on how it is developed.” In the case of Guangzhou, the extensive built infrastructure exacerbated human impact and the CPC was attempting to reverse that with permeable infrastructure that would mitigate human impact.

The 2015 strategy to rebalance the socio-ecological relationship hinges on the ecological civilization concept. The concept was fleshed out with guidance from a partnership between China’s largest source of urbanization funding, the China Development Bank Capital (CDBC), a San Francisco-based environmental solutions consultant, and a grant-making charity organization. The “12 Green Guidelines: CDBC’s Green and Smart Urban Development Guidelines” provide a foundation for sustainable urban development and set measurable, beneficial, and practical standards for those at the city manager level. As of January 2016 the centrally developed guidelines were being used in Nanjing’s Yuhua District and Shijiazhuang, near Beijing, as two pilot cases, with $15 billion in funding from CDBD.

The guidelines are written in a format that makes it an accessible tool for city managers to obtain private partnership funding, garner civil sector support, and facilitate implementation. Reading through the document, in fact, is similar to reading through the case study reports posted by C40 Cities’ members on their web sites. The 12 guidelines include economic, environmental, and social benefits; list payback periods for new technology and return on investments results; use U.S., UN, or European country’s standards; and highlight best practices in exemplary models. Although it is a recent convert from the climate laggard to aspiring climate leader category, China appears to be

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55 Huang et al., “12 Green Guidelines.”
56 Ibid.
58 Huang et al., “12 Green Guidelines.”
taking advantage of networking and collaboration to leap forward and make up lost time to address pressing issues that are clearly in their national interest. This networking includes TCN membership and Guangzhou is one of China’s nine new megacity members of C40 Cities.59

None of China’s cities has yet joined CDC—the Rotterdam-led specialized sub-network within C40 Cities—but Rotterdam’s influence is apparent in one of the PRC’s newest initiatives. Becoming a sponge city has been one of Rotterdam’s goals since 2007, when their adaptation strategy shifted from hard defense against the water to living with the water.60 Beyond climate proofing, as discussed in the section on the Rotterdam adaptation case, the Dutch have been exporting their expertise, including that which makes cities permeable. Evidence that climate adaptation innovation has flowed over the Maritime Silk Road between these two old trading partners emerged in the 2014 technical guidelines document, and was reinforced when President Xi used Rotterdam’s terminology to announce China’s 2015 initiative to create 16 sponge cities.61 Sponge cities would address “too much water,” “not enough water,” and land subsidence problems by replacing gray expanses of cement and other hard surfaces with ecologically friendly, permeable surfaces that absorb, retain, and help store rainwater.62 They would add ponds, filtration pools, and wetlands; maximize the use of bioswales; create plant-filled roadside ditches; and grow green public spaces.63 New cities would be planned and built from the ground up following this concept and utilize new technology and engineering techniques. Existing cities would alleviate flooding and waterlogging by clearing and expanding drainage systems, collecting and reusing rainwater rather than letting this natural resource run off

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as wastewater, and treating polluted bodies of water.64 The policy shift from climate change denial and accepting losses to reducing losses through an innovative approach combining urban spatial planning with engineering and biological facilities to optimize water management was likely driven by economic and political factors.65 Specifically, the CPC has the monetary resources to reduce the risk of climate change and seeks legitimacy that participation—and issue leadership—in international institutions and transnational networks offers.

The central government provided each selected sponge city 400-600 million yuan ($58.4-$87.5 million) annually for three years, but was looking for a private-public partnership (PPP) venture model for green construction.66 Cities able to arrange PPP funding received an additional 10% subsidy from the central government as a bonus for their resourcefulness.67 The innovation has attracted private investors, including foreign firms, such as Dutch and Australian, that see an opportunity to test water management and sponge technology on a scale much larger than available to them domestically.68

Guangzhou was one of 16 existing cities selected to start the project in 2015 and by July 2016, its first pilot sponge city neighborhood, Da Guan Wetland Park, opened.69 The 116.14-acre (47-hectare) man-made wetland park replicates nature by functioning as a rainwater purification and storage system for the city.70 It is a key component of the city’s infrastructure that complements the existing, inadequate, concrete drainage and storage systems. The national sponge city program was expanded by another 14 cities in 2016, with a goal of 80% of all cities becoming sponges by 2030.71 A recent report from the Beijing Times stated that despite 10 of the 30 pilot sponge cities being saturated,

64 “Factsheet Sponge City Construction in China,” Government of the Netherlands.
70 “Pilot ‘Sponge City’ opens in Guangzhou.”
“waterlogged,” during the heavy rains in the summer of 2016, they are not considered a failure and the central government was going to accelerate the initiative’s development.\textsuperscript{72} The term \textit{waterlogging} is used when “rainwater exceeds the capacity of the city to store water and prevent flooding.”\textsuperscript{73}

The monsoon rains early in the summer of 2016 that caused the 10 pilot cities to waterlog hit Guangzhou particularly hard.\textsuperscript{74} In one day of torrential downpours the city received 1.85 inches (3.81 cm) of rain on average, with one district being swamped under 6.5 inches (16.5 cm), which overwhelmed the older man-made concrete drainage system as well as the new man-made spongy wetlands.\textsuperscript{75} Newspaper articles covering the flooding reported that metro stations were “underground rivers,” noted that a dozen manhole covers were swept away, cited more than a meter of water on some roads,\textsuperscript{76} and called Guangzhou a contender for the “Venice of China.”\textsuperscript{77} Figuratively the title may fit, however, literally it does not fit modern day Guangzhou because of the significant changes in the city’s function, population, and scale. A century ago, locals in Guangzhou accommodated monsoon flooding; in fact, their agricultural economy depended on the monsoon rains that fed the rivers and replenished the delta, whereas monsoons today are detrimental to the urban economy. Current Guangzhou residents do not have the skill sets or experience in adapting their behavior to accommodate the city floods because they are predominantly immigrants from non-delta regions. And, unlike Venice, Guangzhou’s location on the mainland does not constrain its paved, landward expansion so the city has grown exponentially.

\textsuperscript{73}Ibid.
\textsuperscript{74}Ibid.
This persistent flooding portends the scale of the problem that Chinese port cities, and the country, face and proves that China’s protracted national policy of denial—accepting losses—that facilitated economic development at the expense of the environment was a risky and costly decision. Those that deny scientifically proven climate change have another agenda and China’s was economic growth. Fortunately for China, it was not endowed with an abundance of fossil fuel resources, which removes potential special interest group spoilers from the decision-making process. Once the PRC had the financial capacity, which gave it the political wherewithal to publically address the problem, it could proclaim enlightenment on climate change and forge ahead with innovative solutions and a path to transition to renewable energy. At their scale especially, a combination of adaptation and mitigation climate action is essential for an effective strategy.

**Analysis. Bringing the Feng Shui back in**

The analysis for Guangzhou is focused on the main points that this city's inclusion was intended to contribute to the study. Primarily, that the type of governance in China has the strongest influence on Guangzhou’s options and decisions regarding its adaptation strategy and, secondarily, it contributes its grand scale as a test site for the combination of engineered and biological adaptation technologies.

Unlike Rotterdam, where the study of the city’s adaptation necessitated a study of the country because of its small geographic size and massive and expensive engineering works, the study of Guangzhou necessitated a study beyond the municipality’s borders because of the Chinese political institutions. Communism, socialism, and even market socialism are characterized by strong centralized control and authoritarianism that severely limit non-state actor involvement and mayoral authority. Historically, locals of the Pearl River Delta institutionalized sustainable methods of extracting economic benefit from the ecological resources in their dynamic environment. However, that pattern was broken in the mid-20th century when the CPC came to power and centralized authority, and then was further dismantled in the 1980s with the enforcement of sweeping economic reforms that spurred industrialization and urbanization. Guangzhou, like all other cities, was on the receiving end of decisions that flowed from the ruling CPC through sub-national regional layers of government down to the city. Governance contributed significantly to increasing
the risk level of the flooding hazard in Guangzhou and overrode all other factors influencing the city’s adaptation policies and, ultimately, controls its resilience.

There are pros and cons associated with the CPC’s strong centralized control. On the positive side, decisions made unilaterally without discourse, debate, or resistance as they move down through the levels of government are expedient. Guangzhou’s dire predicament demands timely action—with a rate of SLR over the past two decades being 1.7 times faster than the global trend, time is not on its side. Although the CPC is culpable due to its decades of climate change denial and under-appreciation of the need for sustainable natural resource extraction policies, their abrupt pivot toward innovative adaptation is better than one delayed by years of debate between myriad stakeholders, a process more characteristic of a democracy, such as Venice. China’s firmly institutionalized authoritarianism and its associated lack of social dissent is advantageous for fast and far-reaching change.

Another advantage of centralized control for Guangzhou is that the CPC provides the means for spongification. The projects are centrally managed and supported by the Ministry of Housing and Rural-Urban Development, the Ministry of Finance, and the Ministry of Water Resources, which means the specifications, assistance, guidance, partial funding, and measures of effectiveness are all provided to the city to streamline implementation. Guangzhou benefits by being safeguarded to a higher standard of protection against floods because of China’s risk aversion, and the city benefits from federal augmentation of its financial capacity. However, critics point out that functional stove-piping of federal departments results in a lack of horizontal coordination and conflicting agendas, which may negatively impact the tri-ministry sponge city project management.

There are two apparent disadvantages of China’s authoritarianism for Guangzhou: a lack of local involvement and systemic corruption. Both of these factors raise the risk of maladaptation. The government controlled adaptation program is in stark contrast to the gradual, locally developed land use and water management practices that were common.
and effective, in China’s delta settlements through the last of the Chinese dynasties (i.e., Qing Dynasty 1912-1916), when these functions were the responsibility of the private sector.81 The linkage of these traditional process characteristics to effectiveness—resilience—aligns with the literature on ecosystem management, which argues that the exclusion of local involvement diminishes the probability of success.

Authoritarian states characteristically do not empower local stakeholders, or tap local knowledge and expertise during the decision-making process, or integrate development planning through the hierarchical levels of government. From the available literature on China’s adaptation to climate change, the decisions of whether, how, when, and where to spongify sections of Guangzhou were not made locally or with local input, which removes the urban policy learning process and sense of internally developed commitment to the project. There is a certain level of local commitment invoked by the CPC, however, as the mayor is responsible to execute the national government’s program, on time and at cost. Fear of missing schedules or exceeding budgets, and incurring the associated political or corporal punishment, generates commitment, as does the positive incentive of political gain rewarded for compliance.82

Rigid control discourages any initiative to challenge the suitability of directed solutions and also eliminates feedback that could be valuable to China’s centralized planners. This drawback was identified by an urban planner at a Beijing-based design firm who expressed concern over Beijing choosing a single sponge city design and applying it to every flooded city in the country, regardless of their individual geophysical characteristics and different water issues that require tailored adaptation solutions.83 The scale of the situation in China, its authoritarian state system, and its governance tradition favor a mass production approach.

The second disadvantage is assumed based on the higher level of institutionalized corruption often found in a single party political system and on research of the referenced material. The manner in which Chinese corruption could impact Guangzhou’s adaptation

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83 O’Meara, “Why China Wants to Build Something...” Author quotes Andrew Buck from Turenscape.
project are through poor quality construction, inadequate monitoring, and false effectiveness reporting that can result in defective workmanship and eventually malfunctioning projects. Corruption combined with a lack of local commitment raise the risk of implementing ill-suited and/or defective measures that will not be effective solutions. These two factors caused MOSE to fail in Venice, which shows that these characteristics can exist in either type of governance—democratic or authoritarian.

Pulling this together, the question is whether the expediency and strong federal support will override the lack of local involvement and potential for corruption. Can an authoritarian government rebalance society's relationship with the environment into a sustainable ecological civilization? Sustainable SES relationships are, by definition in the resilience literature, managed by local stakeholders supported by a polycentric governance structure. However, more empirical studies are conducted on municipalities governed by democratic states than authoritarian states thus adding value to monitoring Guangzhou’s progress. Scale may also be a factor. There are more empirical studies on the influence of local stakeholders and knowledge on resilience in smaller cities, such as Rotterdam and Venice with populations under a million, than mega cities, such as Guangzhou with its population of 13 million. Of the limited options China has within the constraints of time, money, and other models to choose from, their innovative approach, albeit with a keen eye on potential economic gain, seems the most promising, in theory. The proliferation of flooding events will provide ongoing feedback about the appropriateness and effectiveness of their adaptation strategy in making Guangzhou resilient.

Addressing whether the Guangzhou case study supports or falsifies the three hypotheses is next. The first hypothesis refers to C40 Cities’ tendency to promote hard engineered protective adaptation measures over the more politically contentious behavioral modification. The lack of information on how and at what governmental level Rotterdam’s spongification methodology reached Guangzhou make this difficult to answer accurately, although there is a high level of confidence that the idea originated in Rotterdam and made its way to China. The second hypothesis, which addresses horizontal

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city networking among C40 Cities’ members that would bypass a vertical blockage and preempt bottom-up development of adaptation, also cannot be well tested by this case. Guangzhou did not join C40 Cities until 2015 and the decision for innovative adaptation appears to have originated at the top and been delegated downward. However, hypothetically, there could have been pre-TCN bilateral city level networking and the mayor of Guangzhou could have elevated this good idea to the national level. The opacity of intra-China political interactions prevents anything beyond conjecture.

In the literal sense, it is unclear if the third hypothesis is supported by the Guangzhou case study. The literature does not provide proof that the floods of 2010 and 2013 were the key factors that influenced the CPC’s paradigm shift in adaptation strategies from denial to reducing losses and subsequent expenditure of significant financial resources for spongification. However, a conjecture can be made based on the data available, that the two recent abrupt and deadly weather events significantly contributed to the policy change. Before 2010 Guangzhou had not had a deadly flood since 1931. The storms were catastrophic in loss of life and property, but they also put domestic political pressure on the CPC. However, they alone are not likely to have caused the change, which would support hypothesis number three: “Abrupt and catastrophic weather events are a necessary, although not sufficient, condition for adopting an adaptation strategy that requires either an allocation of significant financial resources or entails a significant change in land use policy.” In combination with two other conditions, China’s strong economic growth and political ambition toward international leadership, the storms may have become a sufficient condition.

In summary, China’s federation structure of single party authoritarianism shifts the decision-making process, assumption of risk, burden of financial responsibility, and influence of special interest groups away from Guangzhou and to the national level. The delta city’s mayor was relegated to implementing the adaptation project and dealing with the effects of flood damage until the new measures were functional. To China’s credit, it broke from a long history of hard-engineered structural flood controls, ignoring recommendations to build more and taller dikes, and heeded advice that higher dikes

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85 Han, Hou and Wu, “Potential Impacts of Sea-Level Rise on China’s ...,” 92.
raise the risk of catastrophic failure. China’s choice of an innovative solution that combines urban planning, engineered, biological, and behavioral measures to address their pressing problems of urbanization, pollution, and poor water management has the potential of benefiting them in four ways—economically, socially, politically, and environmentally.

If the sponge cities succeed, a portion of the projected $687 to $13.2 billion in average annual losses will be averted for a mere $60-$90 million annual investment, which is a substantial economic gain. Also, China will be able to export to the growing international market its scale-proven technology and expertise for additional economic gain, following the Dutch model of commodification through TCNs. Less frequent and severe flooding will benefit the commercial and civil sectors of society through increased productivity and less damage to infrastructure and property and quell social unrest, which equates to political gain for the CPC. Lastly, spatial planning that incorporates the Chinese philosophy of feng shui will allow the environment time to heal itself so that the socio-ecological system of Guangzhou will be more resilient to climate change.

What this case provides is insight to both the scale of a megacity and the dynamics of a city micro-governed by a single authoritarian party that controls the political and economic systems. The former characteristic of scale takes the case outside the parameters of resilience case studies. The sheer size of the city, which is larger than many nations, and the rate of urbanization negate any expectation of historical local knowledge playing a role in decision making. If the ecological-civilization-from-above directives prove effective, then the Resilience literature’s consensus that local knowledge and commitment are imperative for success would be challenged. Perhaps the literature’s list of desirable characteristics as gleaned through research on smaller, more democratic cities does not scale. There may be a size beyond which other characteristics make a city more resilient. Using the characteristics that contribute to Rotterdam’s resilience to evaluate the resilience of Guangzhou—a megacity under centralized governance—may result in a false negative. One size never fits all. This makes further research into similar case studies worthwhile.

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86 Vander Klippe, “China’s Sea Change.” Author cites Chen Tegu, professor emeritus at the South China Sea Institute of Oceanology of the China Academy of Sciences in Guangzhou.
87 Hallegatte et al., “Future Flood Losses...,” 2-3, tables 1 and 2. Average annual loss figures of $687 million and $13,200 million are from 2005 and 2050, respectively.
The latter characteristic (i.e., communism) forces the unit of analysis to the national level at which decision making for the city is made quickly and without discourse or debate. This shorter timeline is an interesting contrast to the protracted democratic discussions, in that reactions may be quicker and planning cycles can be shorter. Quicker decisions may or may not deliver appropriate and effective adaptation measures; time will be the judge of that. According to the Resilience literature, since the decisions are not made by the city, the local decision makers would not have had the opportunity to develop the processes and practices that result in characteristics displayed by resilient cities. As a result, the CPC’s protective measures would reduce the vulnerability of Guangzhou, but would not have made the city more resilient.
CHAPTER 7

MIAMI

Miami is Denying

The City of Miami is the fourth and last global port city to be used as a case study of antithetical adaptation strategies. The Southeast Florida city’s policy of denying climate change facilitates denying SLR, which accepts the chronic flooding as an historic and usual regional phenomenon that doesn’t justify an adaptation strategy of any consequence. Thus, the conditions are established to maintain the status quo. As the following description and analysis explain, there are influential stakeholders that emplace strong economic and political motives to maximize their short-term, but lucrative gain that would be threatened by the substantive changes necessary to address the increasing flood hazard.

Florida’s geological composition attests to its underwater origins and presages its future. In its less than 120 years as a city during a time of climate stability, Miami City grew to prominence as a tourist destination, real estate goldmine, global maritime trading hub, and agricultural resource of national significance only as a result of man changing the environment. The vast marshlands, swamps, rivers, and coastline required extensive draining, dredging, diverting, and shoring to produce the city and port—similar in some regards to Venice. Unlike Venice, Guangzhou, and Rotterdam, however, Miami did not have any long-term residents with local knowledge and experience in dealing with a gradually worsening relationship between society and the environment. Immigrants arrived in waves, not unlike a series of gold rushes, to exploit the region’s abundant natural resources. Despite the compressed timeline that is Miami’s history, a bias against regulation and an unrealistic risk tolerance became deeply entrenched characteristics that are proving tenacious despite the incontrovertible evidence of accelerating SLR and the mounting costs of hurricane and flood recovery. In a Disneyesque manner, fish swim upstreet in Miami on a sunny day during high tide, yet the development and construction money continue to flow in, almost begging for a catastrophe. These factors, and the
relationships that create this socio-ecological setting, are worth investigating and understanding because they are extreme, although, unfortunately, not unique.

The following description of Miami City places the port city and its flooding hazard in political, economic, and historical context. Throughout this description and into the subsequent analysis, a comparison of Miami Beach’s antithetical adaptation strategy is woven to identify factors that influenced the opposing decisions. Note: The City of Miami is commonly referred to as Miami and Miami City. Miami Beach is a distinct incorporated city.

Description

Florida is a relatively new geological peninsula on the U.S. continent that emerged from the sea for the first time around 25 million years ago, during a colder period when oceans contracted as glaciers grew. When the weather warmed and the glaciers melted into the sea, the low-lying exposed peninsula re-submerged. Geological evidence indicates that there were four cycles of emergence and submergence during this period and that the peninsula’s exposure varied with the sea level, which depended on the global temperature. During the most recent Ice Age, Florida was three times its current size, but it is now shrinking. Figure 7.1 shows the variance in size of the Florida peninsula from its largest footprint 20,000 years ago during the last Ice Age to its present day size to a possible future shoreline with six meters of SLR. This cycle accounts for the composition of Florida’s sedimentary limestone bedrock that was created by the cumulative remains of sea creatures.

This geological history is relevant to Miami’s current situation because it explains two of the three factors that contribute to its SLR and flooding hazard. First, Florida’s dynamic land-sea border is tightly coupled with global temperatures, albeit with a hundred-year time lag. As the temperature and seas rise, the coastline migrates inland. Sea level is the principal determinant of shoreline position.

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3 Ibid.
4 Hansen et al., "Ice melt, sea level rise and superstorms...,” 3790.
5 Leatherman, “Social and Economic Costs ...,” 188.
Second, Florida’s porous limestone bedrock contributes another dimension to flooding—from the bottom up. Venice experienced a similar phenomenon, albeit of man-made origin, with water seeping into San Marco Square through its dilapidated underground water catchment system. Miami’s seepage is natural and is worsening because freshwater dissolves limestone, undermines its foundation, and causes sinkholes. This substrata porosity phenomenon has also created a latticework of underground rivers that emerge as surface springs during high tides or when they are under storm surge pressure.⁷

Neither of these factors was a worrisome issue until people discovered Florida’s abundance of natural resources—temperate climate, fertile soil, and beautiful beaches—and recognized the potential for real estate development and tourism in a verdant paradise. These natural resources and its geographic location in the southeast of the U.S. led to an influx of people in the form of immigration and tourism, which is the third factor that contributes to the flooding hazard for Miami.

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⁷ Leatherman, “Social and Economic Costs ...,” 188.
Southern Florida became an international trade and financial hub linking North and Latin America with Europe and the Caribbean. In the late 19th century, investors were attracted to the economic potential of its strategic location and provided funding to expand the railroad southward, dredge the waterways, and drain inland swamps, thus enabling a mass immigration from northern Florida and the eastern seaboard. The state’s policy of not taxing individual incomes—considered a growth stimulus policy by proponents—provided a further economic nudge to those contemplating a move south. Transportation, tourism, trade, real estate, and international banking attracted more immigrants and the development of southeast Florida really took off.

In 1896 the City of Miami incorporated with a population of 444 residents. Over the next 100 years, the city grew rapidly as waves of returning servicemen (post-WWII), Cuban refugees (1959), Haitian and Nicaraguan refugees (late 1970s), and more Cubans (1980) combined with a steady flow of snowbirds and retirees from the north, and tourists from around the world. In 2016 Miami City’s population was 441,001 and its metropolitan area population burgeoned to 5.56 million making it the 8th largest city in the U.S. Although this area is the fastest growing in the state, the surging population is not limited to South Florida or Miami-Dade country. In 2014 Florida became the 3rd most populous state in the U.S. with 19.9 million people, 78% of whom live along the 1,197 miles (1,926.4 kilometers) of coastline and 2,276 miles (3,362.9 kilometers) of tidal shoreline. And then there is the part-time population.

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10 City of Miami History, official website.
12 Miami Dade Government website http://www.miamidade.gov/info/about_miami-dade.asp (accessed 22 March 2017). The City of Miami is the largest of 34 municipalities in Miami-Dade County, which encompasses 2,000 square miles, is located in the southeastern end of the Florida peninsula, and had an estimated population of 2.7 million in 2015. One-third of the county is located in Everglades National Park.
14 De Freese, “Florida and the Environment...,” 469 and 475. The lengths of coast and shoreline were accurate when the lecture was given, but obviously may have changed because of the dynamics at play.
Tourism continues to grow and 2013 saw a record number of 14.2 million overnight guests visit Miami-Dade County, half of whom were domestic guests while the other half traveled primarily from Latin America.\textsuperscript{15} Tourism—because of its inherent vacancy rate—requires additional infrastructure, beyond what is needed to support the full-time population, which exacerbates the urban footprint and stresses the natural environment.\textsuperscript{16} Hence, there is a cost to Florida’s tourism that may soon outweigh the economic gain it currently provides to Miami.

The influx of people to Miami City, in the form of immigration and tourism, is the third factor. Combining this social factor with the two geological factors of shrinking shorelines and porous limestone foundations causes the high level of population exposure to flooding. As is the case with Guangzhou and many other densely populated waterfront cities, Miami’s urbanization has produced an unsustainable relationship with an increasingly dynamic and unpredictable environment. The changing climate and environment is the next topic.

The tropical climate that attracts people to South Florida and supports a bountiful agriculture industry brings with it a risk of hurricanes. In fact, 36\% of all recorded hurricanes to hit the U.S. since 1851 made landfall in Florida, typically during the August-to-October timeframe.\textsuperscript{17} Hurricane Miami in 1926 and Hurricane Cleo in 1964 were catastrophic direct hits that caused massive flooding, death, and destruction, although there have also been numerous hurricanes that inflicted extensive damage despite being indirect hits.\textsuperscript{18} Whether resulting from direct or indirect hits, the costs of hurricane damage are rising—eight hurricanes caused over $3 billion in damage in Miami-Dade County alone in 2004 and 2005\textsuperscript{19}—in part because SLR brings storms and hurricanes further inland.\textsuperscript{20}

\textsuperscript{17} \textit{Seven counties 50 years Southeast Florida Prosperity Plan}, 127.
\textsuperscript{20} Deyle, Bailey, and Matheny, “Adaptive Response Planning...,” v.
These abrupt weather events are not the full extent of Miami’s problems, however, since the gradual effects of SLR are worsening and causing growing consternation. The chronic inundation, beach erosion, rising water tables, and more frequent and intense tidal flooding are pervasive manifestations of SLR that are challenging and expensive to address. Scientists are studying the historical data, identifying the myriad interconnected variables that influence the processes, and modeling scenarios to scope the future. All of their projections for future SLR indicate matters are deteriorating.

Projections for SLR in Miami require some explanation. As discussed earlier, global mean sea levels and global rates of sea level change are useful metrics for monitoring the Earth’s systems overall, but are not useful for adaptation planning at the coastal city or even regional levels because variance in sea levels and rates of change are often quite significant. Let’s look at the change in sea level over time from a global and regional perspective and then compare the rates of SLR acceleration to better understand what the City of Miami and its Miami-Dade County neighbors face.

Since 1870 the global mean sea level has risen about eight inches (20 cm), which is a negligible 0.06 inches (0.13 cm) a year over 140 years to 2010. The rate of change was not uniform, however. The global mean SLR from 1993 to 2010 was almost twice the rate it was from 1901 to 2010 and this shows a clear trend of increasing acceleration of global SLR in the 20th century. The average for the past 20 years is attributable primarily to the thermal expansion of ocean water (39%) and the infusion of fresh water as glaciers and ice sheets melt (49%). The rate of rise in sea level correlates to the increasing global temperature and the higher levels of atmospheric CO₂, albeit with a time lag.

During the same timeframe, 1870-2010, the sea level in Southeast Florida rose 12 inches (30 cm), which is 50% higher although it represents just 4 inches (10 cm) more than the global rate. The rate of SLR in Southeast Florida paralleled the global rate of

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24 Ibid., the authors cite Mean Sea Level Trend for station 8724580 Key West, Florida, at NOAA Tides and Currents https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8724580.
increase, showing the same acceleration from 1993 onward, but then pulled ahead a
decade ago. Since 2006 the rate of SLR in Southeast Florida has been 0.35 inch (9±4 mm) a
year.\(^25\) This is almost three times the global rate of 0.13 inch (3.2±0.4 mm) and 0.11 inch
(2.8±0.4 mm), depending on whether the data source is satellite or in situ, respectively,
from 1993 to 2012.\(^26\) This is a noteworthy difference that provides a good example of the
significance of the variance between local and global SLR.

The higher acceleration of SLR in Southeast Florida is caused by the addition of
regional factors, such as land subsidence and changes in offshore currents, to the global
factors of thermal expansion and ice melt. Together these factors produce the regional
variance in SLR in Southeast Florida. Land subsidence is more pronounced under dense
urban centers, including cities along the U.S. eastern seaboard, because of extensive
underground water extraction and extensive (i.e., heavy) vertical construction. The former
undermines the foundational strength to support the latter that leads to compression and
land subsidence. In this regard Miami City is similar to Guangzhou and Venice, albeit with
the added porosity of its limestone foundation that further degrades its structural integrity.

The second factor that contributes to this regional SLR variance is ocean dynamics.
Since Miami lies on the western boundary of the Atlantic Ocean, the Atlantic Meridional
Overturning Circulation (AMOC) system and Gulf Stream system are the most relevant
forces. The AMOC is a three-dimensional conveyor belt that transports heat and carbon
from the ocean’s surface to the ocean’s depth as it circulates in a clockwise and downward
movement ranging from the Southern Ocean to the Arctic Ocean.\(^27\) As a heat and carbon
sink, oceans absorb 90% of global warming.\(^28\) This thermohaline circulation is driven by
changes in the water temperature and its salt content. Cold salt water is denser and sinks
from the surface contributing momentum that increases the velocity of the AMOC, whereas

\(^{25}\) Shimon Wdowinski, Ronald Bray, Ben P. Kirtman, Shaohua Wu, “Increasing flooding hazard in coastal
communities due to rising sea level: Case study of Miami Beach, Florida,” Ocean & Coastal Management 126

\(^{26}\) Ibid., the SLR rate in Southeast Florida is since 2006 while the global average rate is from 1993-2012. In
situ data are tidal gauge readings.

\(^{27}\) Martha W. Buckley and John Marshall, “Observations, inferences, and mechanisms of the Atlantic

\(^{28}\) Intergovernmental Panel on Climate Change (IPCC). Climate Change 2014: Synthesis Report Summary for
Policymakers. Contribution of three Working Groups to the Fifth Assessment Report of the IPCC.
warmer freshwater is lighter and floats and slows the circulation.\textsuperscript{29} The AMOC’s northward flow at the surface interacts with the primarily wind-driven Gulf Stream system by both regulating its speed and course.\textsuperscript{30} If all other factors are relatively constant, then, when the velocity of the AMOC decreases (i.e., weakens) the Gulf Stream also slows and changes its course; when the AMOC is stronger the opposite occurs.\textsuperscript{31} There are instances in which the cumulative effect of forcing factors shifts the Gulf Stream away from the shore and on a more southerly path,\textsuperscript{32} and other combinations of factors that cause the Gulf Stream to shift toward the shore on a more northerly path.\textsuperscript{33}

A strong circular flow of the Gulf Stream, see figure 7.2, influences the gradient of the Atlantic Ocean in that the current’s energy pulls water away from the mid-Atlantic coast as it turns eastward which creates and maintains a “hill of water” on the open-ocean side. A 2013 study estimated the gradient differential to be three to five feet high, and notes that when the Gulf Stream slows there is less force pulling water from the shore so the hill flattens and water dissipates shoreward.\textsuperscript{34}

Hence, in theory, the mechanism of the AMOC and Gulf Stream can be affected by climate change to the detriment of Southeast Florida in the following manner. The higher GHG emissions trapped in the atmosphere cause temperatures to rise globally. In the Arctic this increased heat melts the 3,000-meter thick Greenland ice sheet adding freshwater to the North Atlantic.\textsuperscript{35} The freshwater dilutes the sea water and the less dense mixture floats, slows the rotation of the AMOC, decreases the velocity of the Gulf Stream, and diminishes the gradient differential across the Atlantic Ocean, thus raising the sea level along the shores of the U.S. eastern seaboard.

\textsuperscript{29} Hansen, Sato, and Kharecha, “Earth’s Energy Imbalance and Implications,” 3763.
\textsuperscript{31} Ibid., explanation from Stefan Rahmstorf, Professor of Physics of the Oceans at Potsdam University, on video clip on his blog entitled “Real Climate: Climate science from climate scientists.”
\textsuperscript{33} Rahmstorf’s blog entitled “Real Climate: Climate science from climate scientists.”
\textsuperscript{34} “Connection Between Gulf Stream and Sea Level Rise Confirmed by ODU Study,” https://www.odu.edu/news/2013/2/gulf_stream_sea_level#.WN3_lxhh3jB. News article refers to Ezer et al., “Gulf Stream’s induced sea level rise...”
\textsuperscript{35} Rahmstorf’s blog entitled “Real Climate: Climate science from climate scientists.”
The influence of the AMOC stretches from the Greenland ice sheet to the Southern Ocean latitudinally, and from the east coast of North America to Western Europe and Northern Africa longitudinally and, en route, “modulates the trajectory of climate change.” The effects vary by region because ocean dynamics interact with (affect and are affected by) myriad other regional factors, but everyone who lives near the water’s edge would be affected. An illustration of the wide range of this interconnectivity is that Greenland’s shrinking ice sheet is a loss of habitat for both proximate polar bears and distant Floridians.

The Working Group I contribution (The Physical Science Basis) to the Intergovernmental Panel on Climate Change’s (IPCC’s) Fifth Assessment Report (AR5) discusses ocean dynamics and in their review of the science they note “coupled climate

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models find that a slowdown of the AMOC in the next decades is very likely, though with uncertain rate and magnitude," in response to increased atmospheric GHG. The IPCC concludes that the short observational record of AMOC variability precludes a finding of change in the transport of the AMOC, at this time.

This explanation of the numerous interactive and dynamic factors serves as a caveat to the discussion on SLR projections that are essential to inform the decision makers in the City of Miami. When contemplating the type and extent of resources to dedicate to protect the function and identity of their port city, planners must assess the risk for the short, medium, and long term. In fact, this is difficult to do because climate change has reduced the usefulness of historical SLR trends for projecting future levels, and the emergence of previously unobserved natural phenomenon resulting from the interaction of factors produces a wide range of scenarios and models with correspondingly wide-ranging projections. These two factors create confusion that some special interest groups perpetuate to delay action that would change the status quo, in order to protect their economic investment. In the City of Miami this has reinforced a propensity toward denial, as the following will explain.

The acceleration of regional SLR is recent, is diverging from the global rate, and is not yet stable. Had the current rate of rise been the annual rate since 1870, the seas around Florida would already be 50 inches higher and more than one-third of this low-lying state—the southern third—would be underwater. Should this current rate become the new norm, we would expect Miami to reify Atlantis within the next 145 years, although when that would occur within that timeframe is difficult to ascertain because of the interaction of myriad factors.

As previously mentioned in chapter three, Research Design, scientists continue to develop models based on different GHG emission scenarios to predict future potential conditions such as global temperatures, sea surface temperatures, and SLR. The IPCC AR5

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39 Ibid., 284.  
40 Joe Romm, "Scientist: 'Miami, as we know it today, is doomed. It's not a question of if. It's a questions of when,' Think Progress, 23 June 2013 https://thinkprogress.org/scientist-miami-as-we-know-it-today-is-doomed-its-not-a-question-of-if-it-s-a-question-of-when-3b3212be388d#.h0s6dzj5q (accessed 24 March 2017).
was released in 2014 as an update to the Fourth Assessment Report (AR4) and continues to use process-based projections. These projections—Representative Concentration Pathways (RCPs)—are based on scenarios with varying levels of emissions categorized as: stringent mitigation (RCP 2.6), intermediate (RCP 4.5 and 6.0), and very high emissions (RCP 8.5).\textsuperscript{41} Each RCP considers input from several models. For example, 32 models contributed to RCP 2.6’s range of projections and RCP 8.5 had 39 models.\textsuperscript{42} The corresponding global mean temperature change from the lowest level of emissions (RCP 2.6) to the highest (RCP 8.5) shows an increase ranging from 1.1°C to 6.4°C (1.98°F to 11.52°F) and SLR projections that range from 7 to 23 inches (17.8 to 58.4 cm) by the end of the 21st century.\textsuperscript{43}

These IPCC global mean SLR projections provided a starting point to which the Southeast Florida Regional Climate Change Compact (SFRCCC) added the effect of regional factors that explain the accelerated rate of SLR that Miami City is experiencing. These projections were compared to similarly adjusted projections from two U.S. federal agencies, the U.S. Army Corps of Engineers (USACE) and National Oceanographic and Atmospheric Agency (NOAA). SFRCCC used a median value of IPCC’s RCP 8.5 scenario, USACE’s High, and NOAA’s High projections and ended up with SLR projections ranges of 6-12 inches (15.24-30.48 cm) in the short term (2030), 14-34 inches (35.56-86.36 cm) in the medium term (2060) and 31-81 inches (0.79-2.06 meters) in the long term (2100).\textsuperscript{44}

As table 7.1 shows, the IPCC’s highest projection—RCP 8.5—is considerably lower than the USACE High and NOAA High projections. This is primarily due to the IPCC’s exclusion of major ice melt contributions to SLR from the Greenland and Antarctic ice sheets.\textsuperscript{45} Ice sheet dynamics in this environment of climate change remain relatively unknown, thus there is more uncertainty and a lower level of confidence (i.e.,

\textsuperscript{41} IPCC Climate Change 2014: Synthesis Report Summary for Policymakers, 8.
\textsuperscript{42} Ibid., 11, Figure 4, Technical Details.
\textsuperscript{43} Ibid., 10.
\textsuperscript{44} Southeast Florida Regional Climate Change Compact (SFRCCC) Sea Level Rise Work Group (Compact). Unified Sea Level Rise Projection for Southeast Florida. A document prepared for the Southeast Florida Regional Climate Change Compact Steering Committee (October 2015): 4-5. The base year was shifted from 2010 to 1992 for this 2015 update of the original 2011 report based on guidance from the USACE and NOAA because it facilitates direct use of local tide station information.
\textsuperscript{45} There is a minimal inclusion of Greenland ice melt in RCP 8.5 some scenarios. Climate Change 2013, IPCC WG I Contribution to the AR5: 1179.
medium confidence of a likely probability for both the Greenland and Antarctic ice sheets) in predicting outcomes.46

Table 7.1. SLR Projection for Southeast Florida (above 1992 mean sea level).47

<table>
<thead>
<tr>
<th>Year</th>
<th>IPCC AR5 RCP 8.5 (inches)</th>
<th>USACE High (inches)</th>
<th>NOAA High (inches)</th>
<th>City Project Planning Horizon</th>
<th>Project Suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030</td>
<td>6</td>
<td>10</td>
<td>12</td>
<td>Short-term</td>
<td>Low risk</td>
</tr>
<tr>
<td>2060</td>
<td>14</td>
<td>26</td>
<td>34</td>
<td>Medium-term</td>
<td>Most projects</td>
</tr>
<tr>
<td>2100</td>
<td>31</td>
<td>61</td>
<td>81</td>
<td>Long-term</td>
<td>High risk, critical</td>
</tr>
</tbody>
</table>

The purpose of SFRCCC’s document is to consolidate the scientific data produced by the plethora of models and to provide planning and project design guidance to city administrators within Broward, Miami-Dade, Monroe, and Palm Beach Counties. This is to help them answer questions such as: What are the vulnerabilities associated with levels of SLR? How can a city adapt its plans and its short-, medium-, and long-term projects based on these projections? Their guidance is that the lower projections (i.e., IPCC) are appropriate for designing low-risk, easily replaceable projects.48 The range that falls between IPCC’s and USACE’s projections should be applied to the bulk of the cities’ projects, and SFRCCC considers NOAA’s projections suitable for high-risk projects planned for 2060 onward or any critical or difficult to replace projects.49 Although the various SLR projections remain relatively wide-ranging the further into the future one looks (i.e., from 31-81 inches or 78.7-205.7 cm by 2100), this guidance document can be a useful tool for city planners in the region.

46 IPCC Fifth Assessment Report. Climate Change 2013: The Physical Science Basis, 1169 (Greenland ice sheet) and 1174 (Antarctic ice sheet). Ice sheet dynamical changes are defined as “those related to the flow of the ice sheet.” The context is the melting of the Antarctic ice sheet that will bring ice currently resting on bedrock into the ocean either as ice or water that will raise the sea level. WG 1 to AR5: 1172.
47 Ibid., data taken from Figure 1 entitled “Unified Sea Level Rise Projection (SFRCCC, 2015).”
48 SFRCCC SLR Work Group, Unified Sea Level Rise Projection for Southeast Florida, 4-5, figure 1. Report used the median values of RCP 8.5 scenario to represent IPCC’s AR5.
49 SFRCCC SLR Work Group, Unified Sea Level Rise Projection for Southeast Florida, 4-5.
Converting inches of SLR into lost ground and flooded infrastructure quantifies the level of exposure and vulnerability, which can then be used in the adaptation decision-making process. For example, with one-fifth of urban Miami-Dade County lying within one foot of the 2016 sea level, the 15 inches (38.1 cm) of SLR that the USACE expects within 30 years will manifest as 380 high-tide flood events per year.\(^5^0\) This level of flooding surpasses what Venice is currently experiencing and challenges the categorization of high frequency, low-impact flooding as *nuisance*, a term that implies the phenomenon is tolerable. In addition to flooding, one foot of SLR pushes the shoreline landward 100-2,000 feet (30.5-609.6 meters), depending on local topography;\(^5^1\) and 500-1,000 feet (152.4-304.8 meters) of shoreline recession threatens $6.4 billion of the county’s taxable real estate.\(^5^2\) Three feet (0.91 meters) of SLR, which NOAA projects could occur as early as about 2060 and all three data sources project will occur by 2100, exposes $31 billion in real estate and public investments in Broward, Palm Beach, and Monroe counties of Southeast Florida.\(^5^3\) Some barrier islands would become uninhabitable and others would disappear.\(^5^4\) Shoreline recession morphs into economic recession at this point.

There are numerous other problems caused by an elevated sea level in Miami-Dade County. The capacity of the area’s coastal flood-control structures may be reduced by 65-70% because the 6-9 inch (15.2-22.9 cm) SLR that is anticipated in about 20 years will block drainage, which returns Florida to its past days as swampland.\(^5^5\) It is the same problem that the area experiences during high tides and storm surges, although with SLR it will be permanent. SLR also threatens agricultural land—that loss is projected to be as high as 37,500 acres (15,176 hectares) in Florida with a 27 inch (68.6 cm) rise in sea level, well


\(^{52}\) “Tidal Flooding and SLR in Miami-Dade County, Florida (2016.).”

\(^{53}\) Seven counties 50 years Southeast Florida Prosperity Plan, 117.

\(^{54}\) Ibid.

\(^{55}\) “Climate Change and Sea-Level Rise in Florida – an Update of the Effects of Climate Change on Florida’s Ocean & Coastal Resources,” Florida Oceans and Coastal Council, Tallahassee, Florida, December 2010: 19 [http://www.dep.state.fl.us/oceanscouncil/reports/Climate_Change_and_Sea_Level_Rise.pdf](http://www.dep.state.fl.us/oceanscouncil/reports/Climate_Change_and_Sea_Level_Rise.pdf)

within the 1-4 foot (0.3-1.2 meter) range projected by 2100.\textsuperscript{56} In fact, the seven counties of Southeast Florida are the only sub-tropical growing climate in the continental U.S. (at this time) and are, thusly, a source of national food security as well as a source of regional income. Sales of agricultural produce from that area were valued at $2.1 billion,\textsuperscript{57} almost a third of the state’s $6.6 billion crop sales in 2010.\textsuperscript{58} The Everglades and other conservation wetlands would also be inundated, thus impacting Floridians through the loss of their functionality of tempering extreme weather.\textsuperscript{59} Shallow groundwater tables—the Biscayne Aquifer—and well field protection areas located near the shore are the source of 90% of Southeast Florida’s drinking water.\textsuperscript{60} These freshwater resources are actually brackish and SLR-induced saltwater inundation worsens the situation. Saltwater contamination has already made Florida the national leader in the use of desalination technology with 38 water management desalination facilities processing 245 million gallons (927 million liters) of water a day.\textsuperscript{61} The risk of contamination from breached individual septic tanks and eroded and exposed landfill sites would threaten human, marine, and ecosystem health.\textsuperscript{62} Lastly, SLR changes the probability of abrupt and extreme weather events. For example, with a 6-9 inch (15.24-22.86 cm) rise in the sea level predicted by 2030 (refer to table 7.1) the 1-in-100 year flood will be a 50- or 20-year event.\textsuperscript{63}

To sum up, a foot or so of SLR in southeast Florida, which is likely with medium confidence, will bring 380 high-tide floods a year; expose $6.4 billion in real estate; reduce

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\textsuperscript{56} This agricultural land loss is of Florida’s total 9,548,342 acres of farmland. http://www.farmlandinfo.org/statistics/florida.
\textsuperscript{57} Seven counties 50 years Southeast Florida Prosperity Plan, 109.
\textsuperscript{59} Seven counties 50 years Southeast Florida Prosperity Plan, 117.
\textsuperscript{61} Seven counties 50 years Southeast Florida Prosperity Plan, 112-113. These 2012 figures are double the 2005 figures.
drainage capacity up to 70%; endanger barrier islands, conservation wetlands and the Everglades, agricultural land, and drinking water; and heighten the risk of pollution from landfill toxins—by 2030 to 2060. This endangers the health and welfare of residents, visitors, and the ecosystem, and threatens to have a devastating effect on real estate development, tourism, and agriculture, which would cripple the economy. The last component of Miami’s economy is maritime trade and the following section will discuss the impact of SLR on PortMiami.

The Dante B. Fascell Port of Miami, now referred to as PortMiami, is located in Biscayne Bay between the eastward barrier islands and westward mainland peninsula on which Miami City is situated, as depicted in figure 7.3. This new port was built in the 1960s to replace the original mainland port that did not have room to expand to meet the growing demand. It was constructed on three manmade islands—Dodge, Lummus, and Sam’s Islands—that were originally created from the dredging spoils of opening the passage between Miami Beach and Fisher Islands to shorten the passage from the Atlantic Ocean to the mainland port and the Miami River.64

The three little islands were merged and designed to accommodate cruise liners on the northern wharfs and cargo on the southern and eastern wharfs. PortMiami advertises itself as the “Cargo Gateway to the Americas” and “Cruise Capital of the World” with over a million TEUs in cargo and almost 5 million cruise ship passengers in 2016.65 As a cargo and container port, Miami’s location at the nexus of North-South and East-West shipping makes it a key transshipment hub, although its relatively low volume precludes its inclusion in either the World’s Top Container or World’s Top Cargo Ports for 2015. Even the top container port in the U.S., Los Angeles (8.1 million TEUs), is ranked 19th compared to global competitors such as Shanghai with 36.5 and Singapore with 31 million TEUs.66

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However, the Port of Miami’s cruise ship volume (4.8 million passengers) tops the world list followed by Port Everglades (4.0 million) and Port Canaveral (3.9 million), which ranked in second and third places, respectively. This means that these three Florida passenger ports accounted for 12.7 of the 22 million cruise passengers, which represented more than half of the world’s cruise ship business in 2014. The port is the global headquarters for five leading cruise lines and has the infrastructure and services to berth more than 40 ships from 18 different cruise line companies, which underscores its preeminence in the cruise industry. PortMiami is considered the second most important

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67 Image credit: Port of Miami Tunnel Study Public Affairs Program (accessed 21 March 2017). Image is public record.
69 Cruise.me, 5 April 2016 https://blog.cruise.me/top-10-busiest-us-cruise-ports-86558be34f44#4umow8sz6 (accessed 21 March 2017).
industry to Miami-Dade County’s economy and is accredited with supporting 207,000 jobs and contributing $28 billion annually to the local economy.\textsuperscript{70}

From this reckoning, it is apparent that PortMiami is a critical component of the local and regional economies. It is also apparent from the earlier account of the current and future hazards of flooding, erosion, and inundation that are projected for Miami and South Florida as SLR increases, that society and the environment are on a collision course that will take place at the shifting sea-shore border. This next section quantifies the risk in economic terms and compares Miami City’s risk to other global port cities.

Florida has been called the “poster-state for vulnerability to sea level rise and climate change,”\textsuperscript{71} and South Florida has been singled out as being “ground zero” for potential economic calamity resulting from SLR because of their lack of preparation.\textsuperscript{72} The Miami-Dade County Task Force on SLR calls Miami Beach the “canary in the coal mine.”\textsuperscript{73} In addition to these distinctions, Miami was ranked as the global port city \textit{most} at risk to the 1-in-100-year extreme flooding event in terms of assets ($416 billion) and ranked fourth for population at risk (2 million) in 2005.\textsuperscript{74}

A further undesirable distinction is that Miami is one of just a few non-deltaic cities and the only non-Asian city listed in the top twenty (i.e., highest risk) of 136 global port cities projected to have the highest proportional increase of exposed assets from 2005 to the 2070s.\textsuperscript{75} Specifically, exposed assets in 2005 were valued at $416 billion, but by the 2070s that asset exposure is projected to be $3.5 trillion—a remarkable 843% increase—unless Miami takes action to reduce this risk with an effective adaptation strategy.\textsuperscript{76} The distinction of not being a deltaic city means that Miami is \textit{only} a coastal city and does not face the additional risk of river-generated flooding that deltaic cities face. For deltaic cities, the combination of coastal and river flooding, and the prevalence of extensive low-lying

\textsuperscript{70} Miami-Dade County info from PORTMIAMI.
\textsuperscript{71} De Freese, “Florida and the Environment ...,” 475.
\textsuperscript{74} Nicholls et al., “Ranking Port Cities...,” 3, 28.
\textsuperscript{75} Ibid., 27. Ranked 20\textsuperscript{th} of 136 cities with the highest proportional increase in exposed assets by the 2070s relative to 2005, Figure 15.
\textsuperscript{76} Ibid., 30-31. Miami is ranked number one in both tables 4 and 5.
land, raises both the overall hazard risk level and the complexity of devising effective adaptation solutions.\textsuperscript{77}

The other issue relative to vulnerability is that the delta area of large cities is most prone to flooding making it the least desirable place to live, yet it is often where informal settlements of new immigrants and low paid workers are located. This is particularly a trend in Asian megacities with a high rate of urbanization, population density, and unenforced land use zoning such as Jakarta, Kolkata, and Dhaka that each have a very high level of their populations exposed and vulnerable to flooding. For these reasons, delta cities are considered the most vulnerable to SLR, although Miami City has achieved that ranking without being a delta.\textsuperscript{78}

The other distinction of being non-Asian refers to American cities’ ability, in general, to afford a higher level of defense than Asian cities based on the high U.S. “per capita GDP class” compared to Asian cities’ medium to low GDP class—with the exception of Japan.\textsuperscript{79} As Hanson et al. point out in their 2011 Climate Change article, “the USA and the Netherlands are considered the most capable of providing comprehensive high level protection against an extreme event” for their global port cities based on their GDP, yet Miami and Rotterdam’s antithetical adaptation strategies prove that “willingness to protect” is not exclusively wealth dependent.\textsuperscript{80} Case in point, in 2015, GDP per capita in the U.S. was $56,116 and in the Netherlands it was $44,300.\textsuperscript{81} Both countries have ample financial capacity to protect their port cities to a high level of defense, yet it is clear that they could not be further apart on their willingness to protect. Rotterdam is protected against the 1-in-10,000 year event while Miami accepts the same risk as cash-strapped Dhaka by protecting against the 1-in-100 year event.

To this point it is clear that Miami faces a formidable threat of both abrupt and gradual hazards worsened by climate change. By all accounts the threat is existential although there are varying estimates of when the city will no longer be a functional port or

\textsuperscript{78} Ibid., 199.
\textsuperscript{79} Hanson et al., “A Global Ranking of Port Cities...,” 106, table 5. The GDP (PPP) per capita classes are: high >$15,000, medium $15,000-$3,500; low <$3,500.
\textsuperscript{80} Ibid. 104.
be habitable. Despite the plethora of information and ample warnings from myriad credible sources, Miami City remains prominent among a number of cities in Southeast Florida that have not taken action to reduce their distinctly high level of vulnerability. It has not built large barriers to protect the city, nor has it accommodated SLR by raising structures or enhancing buffering ecosystems, nor has it devised a plan for phased retreat from soon-to-be-uninhabitable swampland. Rather, the City of Miami has pursued a policy of denial that manifests as a propensity to study the problem. Despite access to recommendations from the Miami-Dade County Task Force report of 2006, or the regional plan of 2009, or the 2010 report from the Florida Oceans and Coastal Council out of Tallahassee, or the 2011 Green Print report, or the 2012 Seven counties over 50 years regional report, Miami decided not to implement any solutions. And, as recently as 2015, Miami City Legislature passed a resolution to establish the City of Miami Sea Level Rise Committee to further study the issue and provide recommendations for adaptation.

Miami City's path dependency of denying reality and ignoring the impact of climate change has not gone unnoticed, it is not unique, nor is it the only model used by Southeast Florida cities. In a March 2014 article, entitled “The C40 is Missing one of the World’s Most Important Cities: Miami,” the city’s absence from city network engagement was highlighted and questioned. The article makes the case that membership would put a world of resources and information at Miami’s disposal. Since that 2014 article, C40 Cities membership has grown steadily although it still does not include Miami, the city referred to as “ground zero” for SLR.

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82 Authors list three types of adaptation options—protect, accommodate, retreat. Carter et al., 402.
Miami City is not unique. Other mayors in Southeast Florida, including the Miami-Dade County mayor, Carlos Giménez, who categorized SLR talk as doomsday scenarios, are following a similar path of denial, analysis paralysis, and inactivity.

In contrast, however, the city of Miami Beach has implemented an adaptation strategy of **reducing losses** centered on hard and soft-engineered structural measures that have greatly reduced the frequency and intensity of flooding. The city overhauled its aging gravity-driven drainage system with pumps and pumping stations, raised sea walls, increased storage for storm water runoff and installed back-flow preventers to keep high tides from flooding streets and neighborhoods. At the same time the city elevated streets and sidewalks up to 2.5 feet (0.76 meters), yet maintained some sidewalks at the lower, original elevation to provide access to existing businesses. These armoring protective measures are complemented by an ongoing program of beach renourishment—a soft, but expensive buffering protection measure.

This aggressive construction program is attributable to Miami Beach City Mayor Levine, a media mogul and real estate developer, who campaigned for office on the issue of climate change and SLR with a strong message that he had solutions to the city’s problems. His motto in 2013 was “Vote Philip Levine, a businessman and part-time gondolier, for Mayor” and ads included footage of him paddling his kayak through the streets of South Beach on a sunny day. He won; hired a talented team; raised financing for the $400-$500 million program of pumps, valves, elevation, and beach replenishment;

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86 Note: The executive branches of Florida’s 67 counties and 410 municipalities (i.e., cities, towns, and villages) are led by an elected mayor or manager.  

87 Jessica Weiss. “Miami Beach’s $400 million SLR plan is unprecedented, but not everyone is sold,” *Miami New Times*, 19 April 2016.  

88 *Seven counties 50 years Southeast Florida Prosperity Plan*, 117-119.

89 Weiss, “Miami Beach’s $400 million SLR plan...”

“The objectives pursued by beach renourishment projects are to repair the damaging effects of SLR and storm surges and to halt the progress of inundation.”

91 Weiss, “Miami Beach’s $400 million SLR plan...”

92 Ibid.

and has significantly reduced flooding and kept the fish out of the streets. His strategy was a vertical retreat through elevation, unlike the Venetians' vertical retreat through abandonment. Rather than let the sea claim the ground floor of buildings and turn streets into canals, Levine is building up the ground level and pumping water out, prioritizing an image of dryness to keep the tourism and real estate development dollars flowing in. If the measures are effective, the cost of the program will be recouped by reductions in the city's annual economic losses from flooding.

Residents, visitors, and businesses are pleased with the results, although critics fault the mayor’s methodology and cite the short-term nature of the solution. Criticism includes the administration’s use of emergency single-bidder contracts, implementation of untested solutions, an increase in environmental pollution from storm drain runoff, and prioritization of protecting high-end real estate owned by the mayor himself and his campaign supporters. It is “a vain effort to protect an estimated $23 billion of real estate.” Some critics say he did not do enough and others bring up the maladaptive nature of his expensive, short-term measures that create a moral hazard common to other engineering solutions that mask the risk. When the pumps have failed, the businesses located at the original street level flood and, because of their new status of being 'below street level' they are now basements that are uninsurable by Federal Emergency Management Agency (FEMA).

The nature of Southeast Florida’s SLR problems does not lend itself to solutions that have worked for others. Miami Beach officials consulted with the Dutch water experts, but even they were flummoxed by Florida’s porosity and hurricanes, which made their Dutch adaptation model inappropriate. Continuing to seek guidance even during the construction of their elevation project, in May 2016, Miami Beach partnered with the City

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94 Weiss, “Miami Beach’s $400 million SLR plan...” The final engineered “solution” will include a total of 60-80 pump stations in Miami Beach and they are expected to be complete in the next few years.
95 Ibid.
98 Seven counties 50 years Southeast Florida Prosperity Plan, 119. Miami Beach City leaders sought advice from the Netherlands before devising their program.
of Miami and County of Miami-Dade as the first regional group to join the Rockefeller Foundation’s 100RC network as “Greater Miami and the Beaches”. Each mayor has taken advantage of 100RC’s partial salary funding by hiring a Chief Resiliency Officer (CRO). All three CROs are working together on a unified strategy that emphasizes the cross-jurisdictional cooperation that is needed for an effective long-term adaptation solution. Miami Beach’s experimentation may help other cities trying to buy 30-40 years of time until either new innovative ideas and technology emerge, or the inevitability of actual horizontal retreat is so apparent that they have the political fortitude to zone, tax, and relocate or abandon.

On its own, the City of Miami has not yet taken action beyond assembling a team and studying the situation. Although it is more difficult to identify the causal factors in a situation of no action, an analysis of this study’s independent variables in contrast to Miami Beach explains the motivation behind Miami’s inertia.

**Analysis: Gateway to the Americas needs floodgates**

The City of Miami was an ideal candidate for inclusion as a case study because of its characteristics and proximity to Miami Beach, which facilitated a paired city comparison. This following section will examine these characteristics, the influence of special interest groups and risk tolerance, and their interrelationships in greater depth, while comparing the antithetical decisions of the two proximate cities.

Both Miami and Miami Beach face an existential threat from SLR—it is not a matter of if, but when, they will submerge. Each mayor has the same level of mayoral authority, the same responsibility toward his constituents, and the same unsupportive political chain of command. Miami-Dade County Mayor Carlos Giménez, Florida Governor Rick Scott, and U.S. Florida Senator Marco Rubio were all staunch climate change deniers who refused to provide political and financial support to the Southeast Florida mayors.

The lack of political support was made public in an interview during Senator Rubio’s campaign for President in 2016 when he refused Miami City Mayor Regalado’s request to

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100 Comments from embedded video clip in article by Chris Choi, “Video: Get to know City of Miami CRO Jane Gilbert, 12 January 2017.”
acknowledge the impact of climate change on Florida and to provide assistance in reducing
the city’s flooding risk.\textsuperscript{101} The senator denied the mayor’s request and justified his position
as one that protects voters from the unnecessary costs of proposed mitigation climate
action, while not addressing the actual costs voters bear as a result of the increased
flooding. Likewise, Governor Scott’s unswerving denial of climate change has been
publicized by the promulgation of a directive to the environmental regulatory agency to not
use the terms “climate change” or “SLR” in official documents.\textsuperscript{102}

The lack of political support out of Tallahassee and Washington, D.C. had matching
financial support—none—thus leaving the mayors of Miami and Miami Beach to their own
financial devices. Mayor Levine had the political will, business acumen, and ample local
civil support from residents looking for leadership to address the very real problems they
faced daily with nuisance flooding. Despite opposition from the state and many powerful
stakeholders in Southern Florida who had strong economic incentives to maintain the
status quo, he exerted his authority and implemented an adaptation strategy to reduce
losses.\textsuperscript{103}

One distinction between these two cities is political. Rubio, Scott, Giménez, and
Regalado are all Republicans, while Levine is a Democrat. Although the mayoral offices of
Miami, Miami Beach, and Miami-Dade County are officially non-partisan, the correlation of
party position on climate change to outcome on adaptation strategy is evidence that these
mayors followed their political party’s position on climate change. Mayor Levine was not
saddled with the Grand Old Party’s (GOP) political baggage and he exercised the full
authority of his office. Party allegiance and an ability to raise funds from partisan special
interest groups are rewarded by political parties, thus mayors with career ambition are
motivated toward party loyalty. Levine’s efforts enhanced his career. Historically and in
this case, politicians pay few costs of doing nothing.\textsuperscript{104}

\textsuperscript{101} YouTube video clip entitled “Marco Rubio on Climate Change at the CNN GOP Republican Debate from
Miami,” published 11 March 2016. \url{https://www.youtube.com/watch?v=0bKBEnigLEg} embedded in Peter
\textsuperscript{102} Jenny Staletovich and Joey Flechas, “King tide sets stage for climate talks in South Florida,” \textit{Miami Herald},
\textsuperscript{103} Weiss, “Miami Beach’s $400 million SLR plan...”
\textsuperscript{104} Benjamin Barber, “How to fix climate change: put cities, not countries, in charge,” \textit{The Guardian}, 7 May
2017. \url{https://www.theguardian.com/commentisfree/2017/may/07/fix-climate-change-put-cities-not-
countries-in-charge-oslo-}
The utility industry in Florida is a powerful special interest group whose financial donations have successfully influenced politicians and legislation to maintain the status quo. In 2015, the “Sunshine State” generated a mere 0.23% of its electricity from solar, with the remainder coming from fossil fuels and the state’s two nuclear plants. With Florida being the second largest net electricity generating state and third largest electricity consumer—behind Texas and California—the utility companies have a lot at stake. Their two primary objectives are to ensure consumers do not change their behavior to reduce consumption or shift sources to local solar because both efficiency and self-sufficiency through renewable energy decreases industry revenue. The power companies’ financial donations to political campaigns and advocacy have steered legislators toward policy that maintains their monopoly.

Florida is one of four U.S. states that empower their utility companies (i.e., Florida Power & Light, Duke Energy, Tampa Electric, and Gulf Power) to be the sole sources of electricity, which effectively prevents customers from shifting to solar power. Despite harsh criticism that the state policy contravenes efforts to reduce GHG emissions and interferes with market competition, energy industry donations keep the Republicans on message denying climate change.

The denial narrative has been consistently used in Southeast Florida to avoid scaring off tourism and investment in business and real estate development because they are the economic engines of the region. The narrative downplays the existence of the flooding problem, or claims that any effort to mitigate the cause or adapt to the effects are futile and costly. Occasional reference to Florida’s history as a swamp that has been drained and turned into the current paradise perpetuates a misleading impression that flooding is nothing new and, that when it actually becomes a problem, it will be resolved with technology by industrious people.

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106 Ibid.
108 Staletovich and Flechas, “King tide sets stage for climate talks in South Florida,”
109 Ibid., Vice President Gore criticized Gov. Scott and state policy on solar power.
110 Seven counties 50 years Southeast Florida Prosperity Plan, 105. A graphic description of Florida by Marjory Stoneman Douglas is used in the regional report to portray how people have reshaped Florida.
There are two policies that also work against effective adaptation. The first policy is FEMA’s National Flood Insurance Program (NFIP)—it mitigates the socio-economic impact of flooding and disasters on private and public infrastructure, but also creates a moral hazard of increased risk tolerance. In the seven counties of Southeast Florida alone, the NFIP collected $3.6 billion in premiums in 2012, up from $111 million in 1978. Despite that, the NFIP remains chronically in debt (i.e., $24 billion in 2012 and $25 billion in 2017) and is unlikely to ever become financially self-sustaining because the costs of recovery from the increasing hazards outpace premium rates that politicians cannot afford to raise. Here is an example: the Biggert-Waters Flood Insurance Reform Act of 2011 (BW-12) was enacted to financially stabilize the NFIP by increasing subsidized insurance rates 25% annually until the premium reflects the full-risk rate. However, the financial cost to coastal dwelling constituents and the political cost to their representatives of BW-12 proved unbearable. The Homeowner Flood Insurance Affordability Act was passed in 2014 to delay implementation of certain provisions of BW-12. Despite the latter’s tempering effect the combination of the two legislative acts raises the cost of insurance, which acts as a mechanism to force coastal communities to recalculate the cost of not implementing an effective adaptation plan. Insurance was identified as a key factor for decision makers in the Miami-Dade SLR Task Force’s 2014 report that concluded:

“We believe that without a professionally well thought out adaptation plan in place, we risk losing insurability and financial support for our future.”

When insurance becomes prohibitively expensive, some property owners will be forced to drop their coverage, others will move, and the overall effect will be a drop in property values. This leads into the second policy that works at cross-purposes with effective adaptation to SLR—Florida’s tax structure.

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111 Seven counties 50 years Southeast Florida Prosperity Plan, 125, 141.
The state does not tax individual income and relies heavily on property and sales tax as their source of revenue. Specifically, in FY 2010, 42.9% of state revenue came from property taxes compared to the U.S. national average of 35%.\textsuperscript{116} Sales and gross receipts tax contributed 46.9% of state revenue compared to 34% U.S. national average. However, Florida has no individual income tax compared to the U.S. average of 20%. While useful in attracting residents, this tax structure serves as an economic obstacle to changes in land use policy and an economic inducement to politicians to perpetuate the narrative of climate change denial for fear of losing revenue from high-end, coastal real estate development.

Zoning changes, a key mechanism of non-structural protection, that would reestablish beach and floodplain ecosystems to allow for adequate landward migration would reduce the costs of beach replenishment and coastal armoring, and reduce insurance and recovery costs, but they would also reduce revenue from property taxes.\textsuperscript{117} In fact, The Florida Community Planning Act (FCPA) of 2014 that requires local governments to adjust zoning regulations in response to, and in anticipation of, SLR impacts, is the legal support that mayors need to develop an adaptation plan of retreat—horizontal retreat.\textsuperscript{118}

This case study is not as useful as the others in testing hypotheses because Miami City did not participate in a TCN nor any other horizontal networking, that is on record, nor have the periodic storms and chronically worsening SLR become the tipping point that motivates the city to shift from accepting losses to reducing losses. They continue to deny, which indicates politics and economics trump science. Their focus is on the near term rather than the mid- or long-term.

In summary, decision makers for the City of Miami came under strong pressure from both proponents and those against adopting an adaptation strategy. Scientific data supported a trajectory of accelerating SLR, insurance premiums confirmed the increasing costs to residents and businesses, civic pressure on politicians to reduce vulnerability grew as the hazard risk threatened property values. The growing body of scholarship and media

\textsuperscript{116} Corporate taxes are 2.7%, which is slightly less than the national average of 3.0%, and are a negligible source of income in Florida. Liz Malm and Ellen Kant, “The Sources of State and Local Tax Revenues,” Tax Foundation, 28 January 2013. https://taxfoundation.org/sources-state-and-local-tax-revenues/ (accessed 6 May 2017).
\textsuperscript{117} Richard Grosso, “Planning and Permitting to reduce and respond to Global Warming and Sea Level Rise in Florida,” Journal of Land Use & Environmental Law, Vol. 30, No. 2 (Spring 2015): 206-207.
\textsuperscript{118} Ibid. 208-210.
coverage ensured the issue remained in the public’s awareness. Miami has the legal authority in the FCPA and the mayor has the positional authority to act. Also, Miami Beach both set a precedent in Southeast Florida and provided a model of financing and implementing a climate action plan, while C40 Cities and other TCNs offered technical and financial support for myriad adaptation options. However, the proponents were not influential enough to overcome the path dependency of inertia that was supported by special interest groups, tax policy, and politicians that benefited from the status quo. These dominating political and economic interests, while reflecting rational choice motivations to maximize short-term relative gain for select interests, were the primary force behind the maladaptive strategy of denial that protected the status quo at great cost to the rest of society. The decision for “further study” perpetuated a narrative of climate change denial that enabled continued energy consumption and real estate development that disregarded environmental degradation and worsened socio-economic risk.

Miami’s decision is maladaptive, shortsighted, and unsustainable. However, Miami Beach’s adaptation strategy is also maladaptive, for two reasons. First, it placed lop-sided reliance on expensive, short-term, hard-engineered protection measures. Second, it ignored the more politically challenging land use policy changes needed to implement a mid-term strategy of retreat and a long-term plan for abandonment. But, Miami Beach’s approach is a start and it presents a model of delaying the inevitable for a decade or two to proximate and distant fellow mayors facing a bow wave of adaptation decisions as sea levels rise. Of all the maladaptive options available, Mayor Levine overcame the substantive forces of inertia, launched planning in the right direction, and may have chosen the most feasible strategy possible at that time, in that political and economic context. From the perspective of sustainability, however, Levine’s strategy sends false hope to other coastal cities and barrier islands that procrastinating on the necessary decision to retreat and relocate is feasible. As with New Orleans and its system of levees, the mechanical systems that provide a false dry environment in Miami Beach can create a moral hazard by lulling residents and visitors into a false sense that the risk is as low as it appears—until it fails.

This paired comparison case study of Miami City and Miami Beach shines a spotlight on the power of special interests, money, and partisan politics in the U.S. Climate change has moved from the scientific to the political domain with dogma replacing data and
financial contributions to political campaigns deciding climate (in)action. The paired cities also prove to be a useful comparison with the other case study cities, a comparison that begins in the next chapter.
CHAPTER 8

CONCLUSIONS

This final chapter synthesizes the results and analyses of the four case study cities to facilitate a further comparison of the independent and intervening variables, their interactions, and their effect on the dependent variable. Chapters four through seven explained how the economic, social, political, environmental, and in a couple of cases, cultural factors set conditions for the decisions that city stakeholders made when faced with a worsening hazard of SLR-related chronic flooding or acute storm damage. The following comparison adds a dimension of understanding and points out the value of the comparative case study methodology.

The comparative analyses begins with Venice and follows the same order as chapters four through seven with Rotterdam second, Guangzhou third, and ending with the paired cities of Miami and Miami Beach. There is a short summary of each city’s adaptation strategies over time identifying the catalysts for, and obstacles to, change, using terminology from the Matrix of Adaptation Approaches and Options (table 3.1) and Typology of Options for Adaptation Strategies (table 3.2). After the Miami case there is a visual depiction of the direction of change(s) in each city’s strategy, table 8.1.

Following the comparative analysis we take a look at the combination of SLR and intervening factors and how the dynamics affected decisions regarding strategy implementation across the cities. This analysis focuses on identifying similarities and differences that were most influential, or not, and why. Next, we answer the question: “Was C40 Cities a lifeline for sinking cities?” Then there is an evaluation of the applicability and effectiveness of the four mid-range theories discussed in the Literature Review (chapter 2) and the framework from the Research Design (chapter 3) in analyzing factors, actors, and decisions made regarding adaptation in the case study cities. Lastly, there is a discussion of the implications of these findings and suggestions for further research.
Comparative Analysis

Venice and its lagoon – accepting to reducing losses

The Venetians have prioritized non-structural behavioral modification over structural engineered solutions in their adaptation strategy to protect their city and reduce losses from SLR-related chronic flooding. For centuries the locals made minor behavioral adjustments and accepted (minimal) losses as the cost of living in their unique environment. There is an inherent sense of community, with the associated social capital characteristic of the collective collaborating without external assistance, that was built over time, high tide by high tide, that contributed to Venice’s resilience. Occasional protective measures were implemented to reduce losses to a particularly vulnerable neighborhood or building, although the protective structures were not always maintained and fell into decay. These adjustments were coordinated, financed, and implemented at the local level without the influence of external actors. Tourists and other visitors followed the locals’ lead and acquiesced to the detours, galoshes, and raised walkways during high tides or a storm surge assuming an attitude of “When in Venice, do as the Venetians.” This adaptation strategy of frequent behavioral adjustments appears to be the most appropriate from an economic, political, and social perspective. It has withstood 1,600 years of testing.

Following an acute weather event that caused extensive damage requiring expensive recovery, new and external stakeholders were introduced to the adaptation decision-making process. They redefined the nature and perceived risk of the hazard, and used economic incentives and international normative pressure to influence the inclusion of a massive structural barrier to the mix of adaptation measures. Political conditions in Italy were not conducive to proper implementation of this expensive engineered solution making MOSE a maladaptive choice.

The obvious catalyst for the change in adaptation approaches from accepting to reducing losses, which is reflected in buttressing the protect option, was the storm of 3-5 November 1966. However, since MOSE was not approved until 2003, the social and environmental changes that occurred in the 37-year interim changed the context in which adaptation decisions were made. Let’s examine them and the timeline in which they occurred.
The 1966 storm raised the visibility of Venice’s vulnerability to flooding in 1966 to the international level. In 1987 UNESCO declared *Venice and its lagoon* a WHS, which raised the city’s visibility as a desirable destination for tourists at a time when tourism was increasing worldwide. Increased tourism was economically beneficial in the aggregate for the city and state, but not so at the individual level because the influx of money raised prices and the cost of living beyond what some locals could afford. One ramification of this was that as Venetians moved out their influence as, and on, decision makers decreased. On the heels of the WHS designation, in 1988 MOSE was proposed as a measure that would decrease Venice’s exposure to storm damage. During the 15 years of debate over MOSE the international art community, UNESCO, and the hydrological engineering firms aligned into a pro-barrier alliance against the locals, the environmentalists, and the shipping industry. At the same time, tourism increased, the residential population decreased, land subsidence and SLR worsened, and the probability of a 1966-strength storm was reevaluated from a 1-in-800 years (1966) to a 1-in-200 years (2002). The message and money of the pro-barrier group became more persuasive as the worsening SLR eroded the influence of the anti-barrier alliance. All of this took place in a political arena best described as a vicious cycle of civil mistrust, tax evasion, and corruption enabled by a lack of continuous leadership. MOSE was approved in 2003. Construction of the expensive engineering project was swept up into the vicious cycle, and directly increased the level of corruption that eventually compromised MOSE’s effectiveness.

The 1966 acute weather event combined with the social, economic, and political conditions were the perfect storm that moved decision making from the local, small and fast level up to the national, intermediate size and speed level of the adaptive cycle, after 1,600 years of remaining relatively unchanged.\(^1\)

Looking forward, *Venice and its lagoon*’s long-term survivability are questionable without a fundamental shift in approaches from *reducing losses to choosing change*. Both of the transformative accommodation options that were proposed are extreme engineered measures—filling the lagoon so Venice merges with the mainland or “the Dutch solution” of turning the lagoon into a lake mechanically separated from the Adriatic Sea—should be

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\(^1\) Refer to the Panarchy model of nested adaptive renewal cycles, figure 3.2.
studied for feasibility. The best feasibility study would include evaluating the socio-economic and socio-political factors that will be vital to the acceptance and successful implementation of such a fundamental change to the urban landscape. A lagoonless Venice may be more resilient to future climate change, but a cost of survival that includes the city's historical identity may be too high a price to pay.

**Rotterdam – reducing losses to choosing change**

For roughly 2,700 years the Dutch maintained an adaptation strategy of *reducing losses* from abrupt storm-related flooding primarily through the use of hard-engineered structural measures, albeit with a brief sojourn into soft-engineered protective measures that replicated ecological features to manage water.² This more comprehensive approach was abandoned when a cost-benefit analysis of land use prioritized development over sustainability. Since 1900, their path dependent response to storms returned to their traditional reliance on larger and more technically complex protective systems, which proved to be generally effective except in the winter of 1953.

In most respects the catastrophic storm of 1953 was not a catalyst for change, despite its high toll, for two reasons. First, it was an acute event that fit the pattern of their historical type of SLR-related hazard. Had the Dutch coastal defenses not deteriorated because of WWII and post-war neglect, the Dutch would have suffered little loss from the storm. In theory, the structural protection could not be faulted since the shortfall was in maintenance and chalked up to operator error.

The second reason the 1953 storm was not a catalyst for change was that the same decision makers followed the same decision-making process, without interference or influence from external actors. The interdependent and mutually beneficial relationship between the public, private, and corporate sectors is strong and durable in Rotterdam and the Netherlands. It produces a trust that is the foundation for a virtuous cycle of government transparency and accountability, civil participation, higher tax collection, corporate partnership, and provision of superior public services. The result is an economically successful society that negates the need for external economic assistance,

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² Floods of note in Rotterdam occurred in 1287, 1313, 1315, 1421, 1825, 1916, and then 1953.
which avoids any affiliated external interference in decision making. Thus, the Dutch did not change their adaptation approach.

The pattern of constructing larger and more technically complex protective systems was not broken until 2007 when decision makers recognized that the nature of their hazard had broadened to include chronic and gradually worsening flooding caused by SLR. Examining this decision more closely, we see that the socio-political environment was stable, the Dutch economy was strong, and policy decisions were made by stakeholders with a history of taking the long view for the collective good. In other words, all social factors were varying within a small range conducive for further incremental change in the ongoing adaptive renewal cycles. Nonetheless, a paradigm shift was decided upon.

Evidence points to two environmental factors, the scientific data on climate change and SLR and hurricane Katrina, as being the primary causes for the Dutch fundamentally changing their adaptation strategy from reducing losses to choosing change and adding measures characteristic of both retreat and accommodation options. Their comprehensive and forward-looking strategy continues to support extensive and expensive structural protective measures to flood proof infrastructure, but innovative climate proofing techniques and sustainable development policies that include land abandonment and relocation of residents away from high-risk areas are now part of the mix.

Beyond these two environmental factors, there were two other contributing conditions that initiated their change in adaptation approaches. The collective memory of the dikes failing back in 1953 was a lingering fear that hard-engineered structural protection measures could fail, and the failure of New Orleans’ levees in 2005 made future dike failure in the Netherlands seem more probable. For a very risk averse society—a society that funds protection to the 1-in-10,000 year flood—the new accommodation measures that further reduce vulnerability were worth the investment.

The second condition that existed in 2007 when the Dutch were making their decision was economic opportunity. The international community conversations on climate change can be traced back to the establishment of the IPCC in 1988, through the adoption of the UNFCCC in 1992, to the adoption and enforcement of the Kyoto Protocol in 1997 and

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3 Refer to the Panarchy model of nested adaptive renewal cycles, see figure 3.2.
2005, respectively. Little action of note resulted, cities at risk and without national solutions formed TCNs seeking help, and adaptation expertise began to flow transnationally as it became apparent that it was too late for mitigation alone. The Dutch have been world-renowned merchants for centuries and there is no reason to believe economic gain from commodification of their expertise was not part of their calculations. Would they have shifted strategies without the economic opportunity? Absolutely; it was not a necessary condition. Were they aware of the economic opportunity and did it relieve consternation about the massive costs they were going to incur? Absolutely; money matters.

These measures are financially possible because of ample public-private funding/financing and successful commodification of Dutch climate proofing expertise, which is enhanced through their TCN participation. And the measures are politically feasible because the institutionalized decision-making process for adaptation that includes private, public, and corporate stakeholders is unaffected by external special interest groups. Rotterdam has a high level of political will, societal support, corporate social responsibility, and a communitarian social culture that make it socially resilient to ecological dynamics.

**Guangzhou – accommodation to accepting losses to reducing losses**

The early Chinese farmers of the Pearl River Delta applied their cultural philosophy of feng shui to maintain a harmonious relationship with the environment while improving conditions for agriculture. This culturally based adaptation strategy of accommodation lasted around 3,000 years, was abandoned in the late 20th century, and has recently been resurrected in a modern scaled version. This case provides two four-stage adaptive cycles for comparison.

The reasons for abandoning the first adaptation strategy of accommodation were not environmental; they were political and economic. The series of events started in 1949 when the CPC assumed power, centralized governance, and implemented economic policies to spur development and increase their hold on political power. These political and economic policies were not unlike European and American policies during the industrial
revolution in that they were implemented without regard for their effect on the environment. Industrialization started a rural-to-urban migration, which was enhanced by economic reform policies that liberalized the market, which increased the rate of urbanization. The demands of a dense population required increased ground water extraction, cement production, and vertical building that together accelerated land subsidence and SLR. The high rates of construction, energy consumption, and industrialization generated excessive pollution and a degraded environment that limited access to natural resources. This politically driven cascade of events led to a de facto adaptation approach of accepting losses that was reinforced by the CPC’s denial of climate change. This was at the national level.

At the city level, Guangzhou exploded from a city of 1.5 million in 1970 to an unmanageable megacity of 12.5 million in 2015. It was unmanageable for three reasons. First, just the sheer scale of the city required multiple layers of governance below the mayor. Second, the CPC’s centralization of power moved decision making up and away from sub-national governors. Third, an influx of 11 million people to a city in less than two generations removes the meaning of local from being a resident and completely changes the landscape about which any remnants of local knowledge would be applicable. Any meaningful connections between the social and ecological components in this SES were broken.

The second shift in adaptation strategies was a conscious decision to address the ramifications of the first. The prioritization of economic growth and development over sustainability enabled accomplishment of the CPC’s economic and social goals. GDP was up, millions of people moved from living in abject poverty to join the burgeoning middle class, and China was established as a key player in the networked global economy as a developing nation.

These benefits came at a cost and the economic and social costs were rising. Economic costs included environmental depredation, estimated to range between 3% and 10% of China’s annual gross national income; the associated rising cost of providing socialized medical care; and flood and storm recovery costs, measured as an average

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4 Albert and Xu, “China’s Environmental Crisis.” As noted earlier in the study, the wide range of 3-10% reflects various estimates.
annual loss of $687 million in 2005 in Guangzhou alone.\textsuperscript{5} These conditions spurred social stress, unrest, and protest as the growing middle class made demands upon their government for both compensation and an end to the cause of the problems. Social unrest was perceived as a political threat and taken seriously by the CPC.

Thus, there was not a single factor that was a catalyst for China shifting adaptation approaches from accepting losses in order to maximize economic growth in the most unrestrained manner to an approach of reducing losses. Rather, it was a combination of environmental, economic, social, and political factors that interacted with each other to create the necessary and sufficient conditions to reverse policy. Economic prosperity provided China the financial capacity to temper development, repair damage to the environment, and improve medical service provision to those in need, without seeking funding from external agents.

The first mention of this policy shift was the 2011 announcement to a domestic audience of the 12\textsuperscript{th} 5 Year Plan that included acknowledgement of the impact of climate change and a plan for transformative adaptation into an ecological civilization.\textsuperscript{6} Their stated goal envisions recreating the ancient harmonious socio-ecological relationship by employing the metaphysical principles of feng shui in spatial arrangements and urban planning. The international community became aware of the shift away from denial in 2015 during President Xi Jinping’s address to the UN General Assembly. That is when the Chinese president staked out a leadership role as a climate leader in the hopes of reaping international political prestige.

Another influencing factor is the same as one that influenced the Dutch in 2007 and is likely to have originated as an idea during the transfer of Dutch technology for spongification. That is to realize the economic opportunity from exporting scaled spongification know-how to other countries with sinking coastal megacities seeking solutions, such as those in India, Bangladesh, Indonesia, and Vietnam. Asia is being hit the hardest by SLR-related flooding because of both extraordinarily large vulnerable populations and tempest weather. Perhaps One Belt One Road One Sponge will be the next... 

\textsuperscript{5} Hallegatte et al., “Future Flood Losses...” The projection of average annual losses (AAL) in 2070 is $13.2 billion.

iteration of China's economic trade initiative to remake the Maritime Silk Road in a manner befitting climate conditions.

Comparing the two strategy shifts, the first in the 1950s-1970s and the second in the early 2000s to present, we see that there are many similarities and a couple of noteworthy differences. The stakeholders and decision makers were primarily at the national level of government for both decisions and there were no external influences although the Dutch model may have nudged the Chinese toward reducing losses for the most recent change. The environment was a consideration both in reestablishing the health of natural resources and decreasing the SLR-related hazard for the policy shift in 2011, but not in the mid-1900s. Civil society also had a voice in the most recent change, where none was apparent in the earlier decision. In sum, Guangzhou’s adaptation strategy evolved as accommodation, was completely reversed to accepting losses by national political and economic change agents, and then advanced to reducing losses by those same factors with a nudge from climate change and the Dutch model.

**Miami – accepting losses**

Miami is a young city created by entrepreneur businessmen who recognized the economic potential of a fertile, temperate, and well-situated coastal ecosystem. They drained the swamps and built beaches, developed a rich real estate industry, and built a global port that created a powerful economic engine that generates significant returns for investors. The tourist, real estate development, and business investment revenue depend on sunshine and the perception of sunshine. Discussion of climate change, acknowledgment of a flooding hazard, or plans that include a phased retreat threaten that revenue stream. To ensure that an initial step down that slippery slope is not taken, beneficiary special interest groups contribute heavily and have co-opted politicians to maintain the status quo—bright and sunny inertia. Their focus is on messaging denial and on the continued short-term environmental exploitation of Miami via tourism, real estate, and trade, despite a worsening SLR-related flooding hazard. Miami is an example of the “environmentalist’s paradox” as discussed in the Resilience literature, in which people’s wellbeing improves in
the short term as the quality of the ecosystem declines.\textsuperscript{7} In 2005, Miami’s average annual losses were estimated at $672 million and they are estimated to be $2.55 billion by 2050—those are \textit{annual losses}.\textsuperscript{8} However, it appears that until the costs of \textit{accepting losses} exceed the costs of adaptation climate action to \textit{reduce losses}, there will be neither the underlying civil support nor the political will for change.

The comparison with Miami Beach is enlightening. Almost all factors are the same in these neighboring cities—SLR hazard, financial capacity, federation structure and mayoral positional authority, cultural level of risk tolerance, the opportunity to join C40 Cities and other TCN, and powerful special interest groups. All factors, in fact, except for the political party affiliation of the mayor and the individual leadership of the mayor. Mayor Levine, of Miami Beach, aligned with the Democratic Party and special interest groups that favored protective adaptation, accessed Dutch hydrological expertise, and obtained funding. He raised Miami Beach above King tides for a short-term reprieve from retreat.

Miami’s Mayor Regalado, in stark contrast, ceded his authority to those in the GOP and their financial backers. The utility companies, tourist industry, real estate developers, and business investors proved more powerful than scientific data and all the local proponents of adaptation. The influence of money in U.S. politics is a formidable force to be reckoned with and few politicians display the leadership to buck the system; Mayor Regalado was no exception. At this point, the catalysts for maintaining the status quo have stymied decision makers from making a change in adaptation policies that is desperately needed. This is an instance of over institutionalization causing rigidity in a system and fostering power relations, characteristics that are contrary to improving resilience.\textsuperscript{9}

Miami’s strategy of \textit{denial} keeps the city coffers flush despite the occasional fish swimming upstream. Perhaps being “the ground zero of SLR” has marketing potential for Miami’s tourism industry in that the city will be another disappearing destination attraction, like the Great Barrier Reef and Glacier National Park for the new climate change

\textsuperscript{7} Daw et al., “Elasticity in ecosystem services...” This research developed a concept of elasticity in ecosystem services that describes the sensitivity of human wellbeing to variation and change in an ecosystem upon which they have an economic interest.

\textsuperscript{8} Hallegatte et al., “Future Flood Losses...,” 2-3, tables 1 and 2. Miami is the city with the second and sixth highest AAL in the world in 2005 and 2015, respectively.

\textsuperscript{9} Bahadur, Ibrahim, and Tanner, “Characterising resilience...,” 3. Refer to “effective governance and institutions” as one of the ten characteristics of resilience.
travelers.\textsuperscript{10} Since threshold detection in an ecosystem scaled to the size of a city is almost impossible, a tourist would be well advised to book a disappearing Miami trip with travel insurance.

Table 8.1 provides a visual comparison of the trajectory of change in the four cities’ adaptation strategies over time. Rotterdam’s evolution toward \textit{choosing change} and accommodating the realities of an unstable climate environment are the ideal, certainly the most appropriate in all regards when compared to the choices of the three other port cities. Venice is moving in the right direction, but at a pace unlikely to keep pace with its lagoon.

\begin{table}[h]
\begin{center}
\begin{tabular}{|c|c|c|c|}
\hline
\textit{Adaptation Approaches} & \textit{Adaptation Options} & \textit{Key} \\
\hline
Accept Losses & Protect & Venice \\
\hline
Reduce Losses & Retreat & Rotterdam \\
\hline
Choose Change & Accommodate & Guangzhou \\
\hline
\end{tabular}
\end{center}
\end{table}

Guangzhou took a great leap backward but is now showing signs of progress. These two cities are both \textit{reducing losses} and face formidable political and economic challenges to embracing transformational adaptation, via retreat and accommodation. Between the CPC’s centralized control and the Italian bureaucracy, I would favor communism in making the first move. Then there is Miami.

There are not many similarities across the four case cities, which contributes to their choices of antithetical adaptation strategies. Economics and the effect money had on politicians drove the decisions in Venice and Miami, but both cities had vulnerable political institutions and individuals (i.e., Mayor Orsini and Mayor Regalado). The outcome was

worse for the collective in Miami. Economics was not a key factor in the decisions made for Rotterdam and Guangzhou, although the economic opportunity was a positive nudge for both cities. Both the Dutch and Chinese have strong political institutions, the former are flexible and resilient, the latter are rigid. Time will tell how durable the Chinese political institutions are if market socialism tugs society toward democracy. Both governments made appropriate decisions regarding adaptation that they could self-fund, one decision was from the bottom up and the other was from the top down. The economic and political factors and their interplay are the important to understand and further research in these areas across democratic and authoritarian regimes will contribute to making theories about patterns that emerge.

The communitarian characteristics evident in Rotterdam and Venice contribute to their resilience as societies. Rotterdam’s will be more durable because of its stability, whereas Venice’s outmigration of locals and transition to a day-trip museum city makes it unstable and unlikely to remain resilient. If conditions change in either city, of course, these trajectories will change. Guangzhou’s size requires neighborhood analysis to gauge the level of social networking in place. Miami’s distinct populations of locals, immigrants from Latin America, and snowbirds and retirees from northern U.S. states, have created a patchwork of neighborhoods ripe for investigation along the lines of Klinenberg’s and Aldrich’s work.

With the comparisons of adaptation decision making over time in mind, the next analysis will address the intervening variables that interacted to cause such a wide variation in adaptation strategies. The history and future of SLR hazards, as an independent variable, is the starting point since it is the necessary condition for a port city to be included in this study. The history can be comprised of either chronic or acute events, or both, but the intensity of the future threat is dire across the cases. From there, the political, economic, social, and other environmental conditions that combined with SLR add dimensions that distinguish one city from another and explain the varied outcomes—antithetical adaptation strategies. Table 8.2 provides a matrix of the factors that influenced cities’ decisions regarding adaptation and is a quick reference to the following narrative.
SLR and intervening factors

Across the four cities, SLR posed a significant and worsening hazard, especially for chronic flooding. Venice and Miami are more porous than Rotterdam and Guangzhou making their threat more significant in some regards. Ironically, Guangzhou is building porosity in as Venice and Miami struggles to block it; highlighting the criticality of the direction of porosity. Rotterdam was the only one of the four cities in which climate change, rather than direct weather conditions and flooding, was the primary catalyst for a significant shift in adaptation strategies. Their very high cultural aversion to risk underlies their bias to protect to the highest level possible: to the 1-in-10,000 year storm, although they are striving for protection against the 1-in-1,000,00 year storm. Other factors enabled the Dutch to make this change. Those factors are their financial capacity, communitarian culture, political will, entrenched institutions and decision-making processes, and pattern of ongoing incremental adaptations. These continuous and incremental changes made the system flexible and resilient and facilitated the major shift in adaptation approaches in 2007. The strength of the Dutch political institutions makes them impervious to infiltration or disruption by special interest groups. Yet, unlike in Miami where institutions have ossified and partisan politics have produced negative results for the majority, Rotterdam’s strong institutions and traditions of discourse and compromise combined to produce positive results on the issue of adaptation to climate change.

Further, the Dutch inclusion of private, public, and corporate stakeholders in decision making created a cohesive and resilient society. The case of Rotterdam suggests that their long history of managing water translates into a predisposition of taking the long view on urban planning that accommodates for water. This is an appropriate place to interject an observation about the two fundamental concepts of resilience and vulnerability, for ecology and sociology, respectively. Although Rotterdam has had periods of higher vulnerability to flooding, the society has remained resilient. The city has been bombed, flooded, and blasted by North Sea storms, yet the community always held together socially, bounced back, learned lessons, and developed innovative ways to accommodate
water. This pinpoints the distinction of the two key concepts and emphasizes that they are not antithetical, but rather have nuanced distinctions in their definitions.¹¹

<table>
<thead>
<tr>
<th>Factors</th>
<th>Venice</th>
<th>Rotterdam</th>
<th>Guangzhou</th>
<th>Miami</th>
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</thead>
<tbody>
<tr>
<td>SLR Hazard</td>
<td>Chronic</td>
<td>Acute</td>
<td>Chronic</td>
<td>Chronic</td>
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<td>Fed Gov’t Structure</td>
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<td>Decentralized</td>
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<td>High</td>
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<td>Special Interests</td>
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<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
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<td>Risk Tolerance</td>
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<td>Very Low</td>
<td>Moderate</td>
<td>High</td>
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<td>C40 Cities</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

In Guangzhou climate change did not produce a shift in strategy until other conditions were present, making SLR a necessary but not sufficient condition for change. The mounting economic and social costs of SLR combined with the costs of environmental pollution were on the debit side of the ledger. The credit side was comprised of the CPC’s financial capacity, with the incentive of potential economic and political gain. The lack of transparency of decision making made it impossible to know whether the economic opportunity of exporting innovative technology was more influential than the status of political leadership in the climate action issue area on the international stage. I surmise not, and, in fact, the potential for China to increase its international leadership role has risen since the U.S. is no longer championing support for the Paris Agreement at the national level. Leadership in this issue area has the potential to boost the status, credibility, and soft power of China on the global level and may prove fungible in other areas. There is no reason this would not have been thought through by CPC leadership and seen as an opportunity to reap political rewards. With these conditions in place, and in keeping with their moderate aversion to risk, SLR became a catalyst for changing adaptation strategies.

Miami is similar to Guangzhou in its history and future of SLR hazard because the primary threat is chronic flooding exacerbated by urbanization. Neither of these two cities has had a world-class storm, unlike Venice and Rotterdam, but both are sinking fast and the threat of future storm surges increases with less stable climate. Neither city has a history of locals dealing with the problems of SLR because Miami is a young city with a significant proportion of part-time residents (i.e., snow-birds and tourists) and Guangzhou’s residents recently immigrated from elsewhere. Native Americans and early Pearl River Delta settlers both had sustainable relationships with their environments, but current residents are not related to those who lived there centuries ago and there is nothing sustainable about the current relationships.

Another similarity is that Miami’s and Guangzhou’s mayors both had political bonds that constrained their initiative. Guangzhou’s constraints were inherent in the authoritarian nature of communism and of no surprise to a political scientist. Miami’s were self-imposed despite holding a position that had an inherent high level of autonomy, authority, and the financial capacity to affect change—at least in theory. The difference here is that the national government in China took the initiative for adaptation to SLR while the U.S federal government did not do the same for Miami. In this regard, decentralized decision making did not produce an appropriate result and the costs of this maladaptive strategy will be borne by many if the global port city incurs losses from flooding or storm damage. This position implies a high tolerance for risk, which is consistent with the literature on U.S. city levels of protection.

Venice has a long history of chronic tidal and SLR-enhanced flooding and an equally long history of appropriate behavioral adaptation consistent with their moderate tolerance of risk. The 1966 storm triggered a series of events that created conditions that were sufficient to cause a shift in adaptation policy to one that included a hard-engineered structural measure. As was the case with Guangzhou, the decision was elevated to the national level, but the decision-making process was not the same in Italy as it was in China. The cross scale interplay of the Panarchy model of nested adaptive renewal cycles provides a framework to compare the processes and highlight differences.\textsuperscript{12} With China’s centralized

\textsuperscript{12} Refer to figure 3.2 and the Panarchy model.
control the cross scale interplay is institutionalized and structured to be efficient without an emphasis on discourse. Intermediate and large decisions can be made quickly. The democratic political structure in Venice and Italy is one of decentralized decision making, open power struggles between levels of government, and endless discourse that makes even small decisions slow. Despite those differences, both political systems displayed corruption and neither was well trusted by civil society, although the Italians received much more media coverage and the entire process was more disruptive. The primary disruption to Venice was the infusion of highly risk-averse external stakeholders and a bow wave of money that made a dysfunctional political system more so, thus hindering faster progress toward an adaptive change.

**Was C40 Cities a Lifeline for drowning cities?**

The role that C40 Cities played in the case cities’ adaptation decisions deserves additional attention because it was a focus of this study. Based on the Transnationalism literature, including the work on the agency of networks (i.e. Actor-Network Theory, Acuto 2013a), as well as the status that C40 Cities has achieved based on its membership of global cities, I had an *a priori* assumption that through membership a city would be guided to an appropriate adaptation strategy. Additionally, a couple of questions were posed in chapter two’s literature review about TCNs and C40 Cities’ influence, which will be addressed along with two of the study’s three hypotheses that concern the role of C40 Cities.

Three of the four case cities were members of C40 Cities and each of the three made decisions regarding adaptation to SLR that moved them in the right direction along the continuum of resilience. Miami did not join and did not take adaptation climate action. A generalization about a causal relationship between membership and appropriate adaptation action, however, cannot be made based on these four cities for three reasons. First, case studies are not suited for making broad generalization. Second, C40 Cities’ membership requirements screen for cities that exhibit a commitment to take climate action to mitigate the causes of global warming and adapt to the environment of climate
instability for the wellbeing of their city, as was discussed in chapter three.\textsuperscript{13} The other bundled characteristics of member cities are a propensity to network, global city-ness, problem acknowledgement, and the political will to allocate resources for climate action.\textsuperscript{14} If anything, these three member case cities—Venice, Rotterdam, and Guangzhou—validated C40 Cities’ screening process in selecting appropriately motivated cities with a willingness to protect. Because of that, it is not clear if these cities would have made the same decisions had they not been members or if C40 Cities made a difference, and if so, to what extent. Without further insight to the case cities’ actual interaction with the TCN and an account of how that interaction aided or dissuaded in making decisions, there is not enough evidence to credit C40 Cities with influencing city decision makers. Discerning that influence would require interviews and research into primary source material with permission from both the subject city and C40 Cities. That is another study.

Third, the timing of membership and the changes in adaptation strategy don’t support a claim that C40 Cities was pivotal in any adaptation strategy decisions. Venice’s deliberations spanned 37 years with the decision for MOSE being made in 2003. C40 Cities was formed in 2005. Guangzhou did not join C40 until 2015, after their second shift in adaptation strategies had been decided by the CPC. However, the Pearl River Delta city may be benefitting from membership since they joined and into the future as they work toward permeability, becoming an ecological civilization, and use the TCN as an information trade route. Rotterdam is the third member city. From all accounts Rotterdam has been more influential on C40 Cities than the other way around. As an early member, innovator city, and founder of the sub-network Connecting Delta Cities that focuses on the issue area of SLR, Rotterdam has played a fundamental role in expanding C40 Cities’ repertoire beyond mitigation into adaptation. And, Rotterdam has taken full advantage of the network to reach out, share knowledge, and make Dutch hydrological engineers available to advance other cities’ adaptation policies to the project phase.

This last point raises the question “What exactly is C40 Cities?” The transnationalism, TCN, and TCCG literature make a strong argument that TCNs are more

\textsuperscript{13} Refer to the description of “C40 Cities’ Membership” under Independent Variables in chapter three, Research Design.
\textsuperscript{14} Ibid.
than the sum of their parts and that their level of agency reflects that. However, this study’s finding is that Rotterdam exemplifies the power that one member city can have, based on the influence it wields within C40 Cities and externally because of its association with C40 Cities. There are other innovator cities and each may be so empowered through their association with C40 Cities. This points to a reciprocal, mutually beneficial relationship between TCNs and their members. Further, these relationships become a dynamic that enhances the agency of both the TCN and its members. Thus, to be clear, the findings of this study do not dispute that the agency of TCNs is greater than the sum of its components. Rather, it proposes that both the TCN and certain members experience an enhanced level of agency that is a direct result of their dynamic and mutually reinforcing relationship. This hypothesis is based on a single case study and would need further research to determine if Rotterdam is an outlier or among other cities benefiting in non-tangible, yet desirable ways from their TCN membership.

Despite its lack of membership, the Miami case contributes to this discussion in that it presents an example of C40 Cities’ awareness of the agency it possesses as an actor and its willingness to exercise said agency. C40 Cities questioned, cajoled, and invited the City of Miami to join, yet Miami did not do so. Mayor Regalado bound himself to his political party, which required he not acknowledge climate change and the problems it was causing his city, much less exercise the authority inherent in his position to take climate action to protect against SLR. These were requirements of membership, but the mayor prioritized his political career over the needs of the city and the impasse remains. This is relevant to the question of whether Miami would have decided to start reducing losses if it had become a member. Because of C40 Cities’ membership requirements the answer to this is yes.

Taking this issue a step further answers one of the primary questions of this study. How does TCN participation influence a city’s adaptation to climate change? One way in


17 This is not to be confused with political self-binding which is usually for the collective good or a better outcome in the future.
which C40 Cities influences cities is through their membership screening process. As a member of C40 Cities one is surrounded only by other cities that are motivated and committed to taking climate action, including adaptation measures, to protect their cities. Inaction is not an option for cities with the means to take action. Those without the means can join and they will have the opportunity to avail themselves of financial, technical, logistical, and planning advice from fellow megacities facing similar challenges. That is the lifeline that C40 Cities provides.

**Hypotheses testing**

Here is a good place to segue into the hypotheses. The first one states: C40 Cities’ best business practices for adaptation to SLR favor hard engineered structural barriers and other protective measures that are more appropriate for wealthy cities at the expense of necessary behavioral modifications that are politically contentious. The second one states: the horizontal networking among C40 Cities’ members will partially bypass the vertical blockage at the national level; however, it may also preempt development of a more locally inclusive adaptation strategy from the bottom-up. Unfortunately, because of the timing of when C40 Cities was formed, when cities became members, and when decisions regarding adaptation strategies were made, these three cases did not provide much evidence to support or falsify these two hypotheses. Further, the lack of transparency in the Guangzhou case pertaining to what authority the mayor has relative to the national ministries running the ecological civilization transformation prevents it from contributing evidence to test the hypotheses.

**In Theory....**

Analyses of these cases were aided to varying degrees by the four mid-range theories discussed in the literature review, chapter two, and the Panarchy framework in research design, chapter three. The following section addresses the application of these concepts in the context of Venice, Rotterdam, Guangzhou, and Miami.
Socio-ecological Systems

As anticipated, the SES concepts were more useful than the SES framework because the theory’s orientation is on people managing the environment rather than my investigation of the effect of the environment on people. Adopting the holistic perspective of the SES and considering the interlinked dynamics of environmental (feedbacks) and social (relationships) change were useful in evaluating how healthy the socio-ecological relationship was in the cities. From the literature, early Guangzhou, pre-1900 and present day Rotterdam, and pre-1966 Venice societies appeared to have a more balanced relationship between the social and ecological components of their SES than during other periods of time. Any balance in Miami would have predated its settlement and exploitation by Americans in the last century. Also, the SES framework would not scale to be applicable to the larger cities; it is better suited to smaller ecosystems and communities.

Resilience and Panarchy

Resilience theory and the Panarchy framework were a good fit to my study. A specific example of an applicable aspect of resilience thinking was considering the questions “Who defines what acceptable levels of vulnerability might be, and for whom, and how such questions are addressed?” 18 This guided the analyses toward identifying actors and factors influential in decision making. Miami City is the prime example of a few economic and political actors overriding all other social actors for adaptation climate action that would address vulnerability, social justice, and environmental safeguarding at the local level. Rotterdam provides the starkest contrast to Miami with the Dutch communitarian culture, pro-activeness, and a very low risk tolerance that goes beyond protecting people and physical assets. They include livestock, wild animals, and ecosystems in their calculations of vulnerable creatures and features worth safeguarding. From an external perspective the level of protection that the Dutch provide can be judged as either admirable or excessive, depending on one’s risk tolerance, time preference, and cost-benefit analysis.

The acceptable levels of vulnerability for Venice and Guangzhou lie between the other two cities based on the decisions made regarding adaptation. For Venice, a mix of

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national, local, and some international actors decided what was the acceptable level of vulnerability for the city, its architecture, and artwork. In Guangzhou, all that was apparent from the data available was that decisions were made at the national level with an inferred medium risk tolerance; to the 1-in-1,000 year flood based on research by Nichols et al.\(^{19}\) Certainly reducing exposure, risk, and hazard to flooding were a priority, and doing so through a mix of behavioral and less expensive engineered measures worked within financial constraints. However, that the reduced vulnerability did not increase the city’s resilience since the decision was not made at the city level. Resilience is a capability, not associated with the level of risk, exposure, and hazard, and external actors cannot apply it to another system.

One of the criticisms of the Resilience literature was that it does not consider issues of agency and power and the relationships and decisions of actors exercising those influences for their benefit in a system. The call for case studies, by Bahadur, Ibrahim, and Tanner (2013) was intended to explore these issues and fill this gap in the literature. The Rotterdam case exemplifies a city having the conditions cited in the SES and Resilience literature that were considered conducive for appropriate adaptation that increases system resilience. Characteristics that were particularly prominent were the inclusivity of the private, public, and corporate sectors in decision making; the trust between civil society and the government; and the city having significant autonomy. One good gauge of autonomy is the mayor’s control of finances and Rotterdam self-reports to C40 Cities that its mayor “owns and operates” “Finance and Economy”\(^{20}\). Other characteristics are risk spreading as operationalized by high taxation and insurance; good communications and collaboration; a reputation of mastering water management that has grown to be worldwide; and wide-ranging institutionalization. A few of these characteristics, such as institutionalization, autonomy, inclusivity, and trust, immunized the SES from external interference by special interest groups and highlighted the agency and power of the city. The combination of all of these conditions in Rotterdam has produced an urban planning

\(^{19}\) Nicholls et al., “Ranking Port Cities...,” 33, table 6. The assumption made for this study is that China has a nation-wide risk tolerance based on their centralized decision making for protection. Shanghai was evaluated as having an approximate protection standard against the 1-in-1,000 year flood, thus Guangzhou should have the same level of protection.

capability that anticipates climate dynamics and builds in accommodation to avoid the disruption release stage of the adaptive cycle. The end result is an effective adaptation strategy and an institutionalized decision-making process that has the ability to maintain a high level of resilience. Because of its monopoly on desirable conditions, at least from the perspective of Resilience theory, Rotterdam does not shed any light on the quandary of “what combination?” and “how many?” characteristics are necessary or sufficient.\textsuperscript{21} However, Rotterdam is resilient and the global port city displays most of the characteristics, thus, \textit{in toto}, the characteristics do seem to be accurate.

The three less resilient cities each had a unique mix of conditions, with certain characteristics in low supply or missing that could be linked to the outcome of lower resilience. Although Venice self-reports that its mayor also controls its purse strings, MOSE was beyond the financial capacity of the city and this compromised its autonomy by opening the door to national and international assistance/interference. Venice needed a bigger purse. Also notable in Venice was the lack of trust between civil society and the government, which impacts inclusivity in discourse, as communications between alliances differ in nature from inclusive discussions among team members. By far the biggest problem was corruption in the public sector that was fed by corrupt business practices that degraded the quality of institutions. The Venice case, then, reveals the importance of autonomy, trust, inclusivity, and institutionalization as conditions that breed resilience, with the caveat that Venice, especially the civil sector, remains relatively resilient with its bias for behavioral adaptation to SLR in the short term. To address the longer term threat will require either abandonment via retreat or a massive reconfiguration of the lagoon and the accompanying political will and financial capability to do so. These accommodation options are beyond the city level of urban planning. In fact, building this level of spatial resilience into \textit{Venice and its lagoon} would be a challenge to the most experienced of landscape ecologists.

The CPC’s centralization of authority and decision making serve to remove Guangzhou from contributing to this discussion. The City of Miami’s lack of adaptation plan and the mayor’s unwillingness to protect the city against flooding reveal the relatively high

\textsuperscript{21} Bahadur, Ibrahim, and Tanner, “Characterising resilience...” Refer to the Characteristics of Resilience section of chapter two based on the referenced article.
level of strength of agency and power of the special interest groups, and the influence of the relationship between the mayor and those groups. The latter being the most decisive in decision making based on the paired comparison of Miami and Miami Beach. Mayor Regalado’s ties to the GOP and heavy reliance on campaign money from the oil and gas industry and utility companies outweighed all other considerations. Since there is no adaptation strategy and discussion of climate change is banned, there is no opportunity to examine Miami’s decision-making process. Thus, there is no insight to their conditions and characteristics. Evidence suggests that the mayor has a very high level of autonomy from the perspective of not being held accountable to the locals who need protection from flooding. On the other hand, he has little autonomy from the Florida governor, senator, and other national level GOP politicians. In this regard, the Republican Party centralizes authority along the lines of the CPC.

**Transnationalism and Climate Change Governance**

By virtue of their functionality as global port cities, all four of the models are deeply networked in communications, transportation, trade, and finance and have a common characteristic of a propensity to network. The flow of ideas and expertise between Venice, Rotterdam, and Guangzhou on the issue of climate adaptation via TCNs such as C40 Cities became apparent in the course of the study, which is not surprising. Less anticipated was learning that C40 Cities may be a current manifestation of trade relationships with historical roots going back to ancient cities along the Maritime Silk Road. The young city that is not a member of C40 Cities, Miami, does not share that historical dimension with the older cities.

What was not apparent in researching the four cities was the role that C40 Cities as a TCN played in governance (i.e., TCCG) on the issue of adaptation to SLR. Although the network facilitated the information exchange and transactions that compose the commodification of adaptation expertise for the three co-member cities, this role falls short of governance. This is apparent when referring back to the definition of transnational governance as “networks operating in the transnational sphere authoritatively steering
constituents toward public goals.” Whether a lack of transparency to C40 Cities’ specific influence on the cities made an assessment of authoritatively steering premature, or the local nature of adaptation climate action with the preponderance of hard-engineered protective measures felt like a mismatch with public goals, these three case models did not invoke confidence that C40 Cities functioned as a mechanism of transnational governance. I would not rule out the governance possibility, however, with cities adopting robust retreat and non-structural accommodation options or on most aspects of the issue of mitigation climate action. Interestingly, their advocacy of Miami City joining C40 Cities with the foreknowledge of the city’s critical requirement for adaptation, rather than mitigation, suggests there may be either more governance going on behind closed doors or that the TCN has aspirations of governance in the future.

**Urban Policy Learning**

Urban policy learning processes appeared to be at work in all four cities to a varying degree, although the never-ending initial information seeking phase appeared disingenuous in Miami City, which found itself in a political quagmire. Through application to the cities, the theory of this process combined well with the adaptive cycle of the Panarchy framework as a subset of the reorganization stage. In the case of Venice, the storm of 1966 was the catalyst for change that brought in other stakeholders and shifted the decision making from a purely local level up to a higher level that involved national governors and international non-state actors. MOSE was rejected at the local level as not fitting in with their internal belief system of either needing a barrier or having trust in their centralized government. Had the decision on policy change to accept MOSE been left at the local level it would not have occurred; however, it was moved out of the local domain and accepted. In this example, if MOSE is considered an adaptation measure taken in response to the 1966 storm, then the reorganization stage took a very long time—37 years. An infinity loop, then, is quite appropriate for the four stages of the adaptive renewal cycle.

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22 Bulkeley et al., *Transnational Climate Change Governance*, 56, references Andonova, Betsill, and Bulkeley, “Transnational Climate Governance.” Referenced book and article are sources of this definition as noted in this study’s chapter two Literature Review section on Transnational City Networks and Transnational Climate Change Governance.
Rotterdam is another example of the two theories working complementarily to explain decisions for change in adaptation strategies. As a densely networked city its exposure to new information on hazards and solutions is extensive, thus the first stage of urban policy learning—external, seeking information—is continuous, as is the evaluation of the appropriateness of various measures—internal, adoption stage. Unlike Miami, Rotterdam’s adaptation strategy is dynamic, with policy changes that reflect influences from both proximate and distant abrupt shocks (i.e., May 1940 bombing; 1953 North Sea storm; and Hurricane Katrina in New Orleans in 2005) and gradual trends (i.e., late 19th century technological, social, and economic advances; and 2007 SLR). The adaptive cycle is tight partially because the multi-scalar (government) and cross-sectional (private-public) decision makers remain constant. Rotterdam’s initiation of new methods of applying technology, governance policies, and business incentives to collectively solve climate change related problems stands out among co-members in C40 Cities, as its designation as an innovator city attests.

**Concluding Remarks**

This study was in response to the call for action on the topic of adaptation climate action by political scientists. Javeline argued that “adaptation is fundamentally political” and this study has shown that to be the case. Each of the four case cities contributed to a better understanding of the issues surrounding adaptation decisions. Rotterdam as a model of cross-sector collaboration, flexible political institutions, embedded learning processes, collective action, and an optimistic attitude that every challenge presents an economic opportunity. Venice provided an example of the struggles between political actors, special interest groups, powerful money, a corrupted system, and the tenacity of locals fighting to retain authority over solving their problems in their own way. Guangzhou was a city that had very few of the characteristics considered conducive to being resilient by the Resilience theorists. Nonetheless, the federal government’s imposition of a robust, innovative, and mixed measure adaptation strategy in record time on Guangzhou may significantly reduce the city’s vulnerability. Lastly, Miami is the epitome of Javeline’s claim.
These four cases all support what political scientists have been saying. Adaptation issues “are less about science and more about political, social, and economic behavior and the institutions that facilitate or obstruct that behavior.” Understanding the physical science, such as the unique geophysical conditions of the city and the magnitude and type of SLR-related hazard, are critical to developing an effective adaptation strategy. Understanding the social science, such as the political institutions, financial capacity, socio-political relationship, and their vulnerabilities to potentially corruptive external influence is key to choosing an appropriate adaptation strategy. As Hoffmann concluded, “the problem with the solutions to climate change is they are social and economic, which makes them political, which makes the super wicked problems.”

The qualitative case studies contribute depth and breadth to understanding relationships over time and across scale and disciplines. The historical, multi-scalar, and interdisciplinary approach used enriched the analysis and enabled understanding the interdependent relationships in the complex adaptive system that is a city. Without these dimensions, patterns and path dependencies would have been missing from the analyses, making it shallow and requiring more conjecture. Thus, in many respects, defeating the purpose of qualitative research.

As it was, there were limitations. Insight to the interactions between cities and C40 Cities was not available and the website data was self-reported by either the member or TCN without critical review. Although unit analysis was at the city level, no city is an island—well, just one in this study—and each city had to be examined in context with its governing state, region, and nation. This, too, adds a dimension. Venice is resilient despite interference from its national government. Rotterdam is resilient because of its symbiotic relationship with a resilient national government. Guangzhou will become resilient if the CPC directs it to become so. And Miami remains at high risk because of limited federal powers and the unlimited power of economic influence to the political system.

In sum, these case studies made it apparent that social factors (i.e., economics and politics) played a more significant role than environmental factors in deciding whether,

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23 Javeline, “The Most Important Topic Political Scientists are not Studying,” 421. Refer to chapter one, Introduction.
24 Hoffmann, Climate Governance at the Crossroads...,” 11-12. Refer to chapter two, Literature Review.
when, and how a city decreased its risk to the hazard of SLR-related flooding. Those social actors may have behaved in a rational manner at the individual or special interest group level politicking to maximize their economic gain, but in the aggregate at the city level the decision made regarding an adaptation strategy was not in the collective best interest.

As explained in chapter three, Research Design, case studies do not provide a basis for generalizations about causal relationships, nor are they sufficient for advancing new theories. These four cases did not explain why cities adopt antithetical adaptation strategies, in general, when faced with a similarly significant SLR-related hazard. However, by tracing the adaptation process of cities to hazards, examining the influence of political and economic actors and institutions, and looking at the effect of historical events and path dependency, this study explained why each of the four cities made the decisions they did. These findings support the consensus that political and economic factors trump environmental factors in adaptation choices. However, when political, economic, and social conditions in the city display many of the characteristics of resilience, the social actors embrace scientific data and plan adaptation that will sustain a harmonious relationship with the Earth life support system. When the balance of power in a society tilts too significantly toward political and economic special interests, solutions are difficult to agree upon. The findings of this study challenge some of the assumptions made in the literature. The communist city case questions the superiority of decentralized decision making and provides a good opportunity for future research.

**Implications and some Recommendations**

To address the “So What?” question requires opening the aperture on why this research and its findings matter. These four global port cities are critical nodes in the global transportation network, which underlies our networked global economy. Losing access after a storm or during their relocations will be expensive and have repercussions well beyond the city, regional, and national levels. They are just four of many ports, but they are not outliers and taking any one port off line affects the entire supply chain.

This study highlights the ramifications of politicizing climate change, in the Miami case, and prioritizing dogma over data. The costs can be quite high, thus there must be a
concerted societal effort to steer the conversation on risk of SLR-related hazards back to facts and cost-benefit decision making. Through this factual analysis, an inclusive and coherent discussion of the trade-offs that can be made over time will lead to better decision making process at the city level.

This recommendation leads to the next one that concerns the appropriateness and effectiveness of adaptation strategies. Rather than basing the decision to adopt a strategy that favors engineered or behavioral measures solely on the type of SLR-related hazard (i.e., chronic flooding or acute and catastrophic events), this study argues that social factors must also be considered. Stakeholders must assess the SES holistically. Scientists and engineers provide excellent guidance on the hazard and structural solutions, but an inclusive team of private, public, and corporate stakeholders must decide if the political institutions are robust enough to implement the necessary climate action. An objective assessment will require a decision-making environment of trust, collaboration, and high valuation on the long-term viability of the port city. An effective strategy is one that reduces the vulnerability of the city. An appropriate strategy improves the resilience of the city. A strategy that does not do both is maladaptive.

Taking this a step further, the most effective and appropriate adaptation strategies will include more than climate action. Measures that improve the social conditions and make it more conducive to an ongoing process of learning and adaptation, implemented along with a series of incremental climate action, would create a virtuous cycle of nested adaptive cycles that enhance the relationship between the social and ecological components of the SES. Curbing the agency and power of self-focused special interests while providing a voice to the most vulnerable segments of the population are the first steps in the direction of a healthier societal balance.

The role of C40 Cities and other TCNs focused on climate issues comes into play here. Beyond peddling expensive engineered solutions, discussions and assistance on implementing behavioral adaptation and devising policies that adjust social institutions to enhance their adaptive capacity would fit well within their mission. It may already be in place, and if that is the case, membership and participation in TCNs hold more opportunities that were apparent in this research effort.
The final note is on adaptation. From a physical scientist’s perspective, all of the adaptation measures discussed in this study are minor adjustments because the scientific data shows the fallacy of thinking porosity, diques, locks, and water storage parks are anything but temporary solutions. Beyond being expensive, they can create a moral hazard and prove to be little more than green-washing. Port cities need to float or move.

From a social scientist’s perspective, port cities are trapped on the edge geographically and city decision makers are trapped in a political economy dominated by capitalism and a governance structure enslaved to that capitalism to various degrees. Transformability is a bridge too far for most cities, at least proactive transformability. Once the storm comes and adaptation measures fail, transformability may be politically feasible. To that end, national government policies for disaster recovery and rebuilding must have a relocation plan in mind and not rebuild in place. The SLR-related catastrophic storm must be allowed to be that catalyst for change.

Future Research

In addition to the suggestions for future research mentioned throughout this study, there are a couple of specific ideas I will propose. Being a proponent of qualitative case comparisons, I see value in both selecting cases on the dependent variable and independent variables. An example of the former would be a comparison of maladaptive adaptation strategies with a focus on teasing out the socio-economic and socio-political factors/actors that influenced the decision. Of particular interest would be identifying those factors and relationships common among co-deniers—those cities living on the edge in so many ways as SLR accelerates. These are the cities that would benefit from policy recommendations.

An example of the latter would be controlling for federation structure, financial capacity, TCN membership, scale, and SLR hazard to see if adaptation strategies differed, and why. This could be a controlled paired city comparison such as Houston and New Orleans in the U.S. compared to Mumbai and Kolkata in India. This pairing would hold constant cultural factors like history, religion, and perhaps risk tolerance, and provide
comparative intra- and inter-state insight. A study that compared megacities such as Tokyo, Jakarta, Mumbai, and New York would control for scale.

Further research into authoritarian governance would add insight to a category sorely lacking in research in the west. This research would test the theory that bottom up decentralized governance is more conducive to resilience at the scale of a city.

Across these studies researchers may develop an indicator of collective action. Perhaps exploration of the correlation between varying tax rates that provide a larger financial base for cities and states and a level of socialism that this study suggests is necessary for expensive adaptive projects. This examines the trade-offs stakeholders consider and weigh in their decision-making process when faced with increasing risk of hazard.

Finally, this body of research may provide a basis for assigning relative weights to the influence of the financial, political, cultural, and environmental independent factors in the decision-making process of city stakeholders in the on-going adaptation to SLR. That would be a useful tool for predicting the type of adaptation measures a city is likely to adopt based on identification of socio-economic and political characteristics.
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APPENDIX A

PERMISSIONS

Figure 3.1 Four-stage adaptive cycle: conservation, release, reorganization and exploitation.
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Figure 3.2 Panarchy, a heuristic model of nested adaptive renewal cycles.
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Figure 4.1 Venice and its lagoon
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Figure 5.1 Land Reclamation on the North Sea Coast

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Figure 5.2 Map of the Delta Works in Zeeland, The Netherlands

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**Figure 5.3** Aerial view of Maeslant Barrier in the Nieuwe Waterweg, near Rotterdam.


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**Figure 5.4** Maasvlakte 2 full planned expansion of Rotterdam port. Requested permission from two sites:

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[http://sea-jobs.net/newsen/266](http://sea-jobs.net/newsen/266)

Source: Article entitled “The largest expansion of the port of Rotterdam,” under Marine World section of News at Sea-Jobs.net: The sea is my workplace.

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Source: Turkey SeaNews International Shipping Magazine online article of 23 June 2014 – 06:13. Article entitled “Rotterdam’s Maasvlakte 2 receives first oil shipment at special berth.”

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Figure 5.5 Map of the Netherlands depicting land below sea level.
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**Figure 7.1** Florida’s shoreline as it was during the last ice age, as it is today, and as it might be in the future.

Image credit and source: Deep Future: The Next 100,000 Years of Life on Earth, by Curt Stager, Thomas Dunne Books, 2011.

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Figure 7.2 North Atlantic Ocean currents
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